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Assessing and Ensuring the Readiness of Future Weapon Systems*

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There is currently a growing debate over the combat readiness of our military forces. On one end of the spectrum are claims that our weapons are considerably more ready than ever, while on the other end one hears that our forces are woefully unready. This sometimes heated debate often rests on two issues of interpretation. First, what do currently used measures really indicate about force readiness? Are we measuring the appropriate characteristics and then correctly interpreting these measures? Second, will future weapon systems be able to achieve needed levels of readiness? Are we increasingly relying on weapon systems that by their very nature cannot attain high states of readiness? These issues are closely related and will probably grow even more so in the future as we rely on increasingly sophisticated weaponry.

This article provides two interrelated insights. First, it argues that meaningful readiness assessment must go beyond the measures currently used. It must take specific wartime scenarios into consideration, and it must provide an integrated view of the complex relationships among weapon systems, their components, and their support systems. Second, it argues that sophisticated weapon systems of the future can achieve even higher levels of readiness when they are subjected to the proper kind of development.¹

Assessing Readiness

Both sides of the current argument often use the same measures of readiness, but they interpret them differently. The most commonly used measures—like the operationally ready (OR) rate and the availability (A_0) rate—are extremely useful for estimating *peacetime* flying needs. They fail, however, to serve as adequate predictors of *wartime capability* since wartime operations differ from peacetime operations in much more than just intensity or scale. Some measures tend to equate readiness with hardware reliability. In so doing, they neglect the importance of wartime operational demands, the number and location of spare parts, and the capability of the support system to maintain and repair aircraft. Yet others emphasize input measures, such as fill rates, which merely measure peacetime “shortages” of spare parts, or utilization rates, which merely measure the peacetime “efficiency” of the support system. These and similar measures are flawed because they in fact assess only isolated elements of the “readiness” system—and not the system as a whole.

Because of such limitations, some observers place their faith in performance measures derived from special surge exercises. Although these exercises serve as excellent training tools, especially when they deploy combat and support resources overseas, they simply do not replicate actual wartime

situations. As a consequence, they cannot accurately predict wartime performance.

To remedy these deficiencies, the military needs a realistic readiness assessment system that first considers specific wartime settings. A question such as “How ready is the 1st Tactical Fighter Wing?” is meaningless by itself. Rather, we must ask “How ready is the 1st Tactical Fighter Wing to meet the combat requirements of specific wartime scenarios?” The description of these scenarios must contain considerable detail involving the initial condition of units, warning time to deployment, time to initial engagement, condition of receiving bases, lift requirements and availability, sortie requirements, threat and expected attrition, timing and volume of resupply, etc.

In addition, such a needed readiness assessment system must integrate the commonly measured characteristics of the weapon system with the quantity and location of important resources and the characteristics and performance of each important component of the support system. For particular wartime scenarios, it must be able to evaluate the readiness both of individual units and of entire theaters. But in so doing, the assessment system must also be detailed enough to identify the causes and effects of individual shortfalls and problems.

Recent advances in modeling capability now permit the development of integrated readiness assessment systems. One such model is *Theater Simulation of Airbase Resources (TSAR)*, which simulates dozens of sortie generation activities both within a base and across a theater of bases. Another is *Dyna-METRIC*, which models the stockage and component repair processes for units and sets of units with given resource and component repair performance levels.² Both models take various inputs and translate them into projections of warfighting capability in specific scenarios. For now, they express capability in terms of the ability to generate sorties of mission-capable aircraft. More direct measures of combat effectiveness, such as tanks destroyed, damage expectancy, or bombers intercepted, are preferred but still somewhat beyond the reach of current methods.

A truly meaningful measurement of readiness thus has several major implications. For instance, measurements that fail to consider a specific wartime context are likely to be useless at best and misleading at worst. Moreover, because readiness within such an integrated context is the product of many influences, each element of the system is a potential target for improvement. These improvement efforts must constantly be coordinated since changes in one system element may affect others. But, most important, integrated readiness assessments show that high states of readiness need not go beyond the reach of future sophisticated weapon systems, although new development strategies will probably be needed to achieve such levels.

Ensuring Readiness for Future Weapon Systems

The many new dimensions of expected wartime scenarios create demanding goals for tactical air forces. These demands in turn create distinct requirements for the hardware that those forces must operate. The growing enemy threat necessitates continued development of weapons with sophisticated countercapabilities, and in turn the environments in which these weapons will have to operate necessitate constant and fundamental changes in wartime support systems.

To allow for rapid employment, redeployment, and dispersal, future fighter aircraft must have a high degree of readiness. They cannot require large amounts of support equipment and personnel for their mission-critical subsystems, such as avionics and engines. The removal rates for mission-critical components, usually among the most costly on the aircraft (a fact that contributes to making large spare parts purchases impractical), must not be too high to permit the rapid generation of fully mission-effective sorties. Finally, in the case of combat avionics at least, there must be increased fault-isolation capability to be able to sustain critical subsystems in fully mission-effective states.

To understand where to direct efforts at improvement, consider the example shown in Figure 1. Assume that in order to increase force response time, flexibility, mobility, and survival—goals necessitated by the projected constraints of future warfare—for the next tactical fighter, we eliminated the need for a deployed Avionics Intermediate Shop (AIS) by creating War Readiness Spares Kits (WRSKs) that contained all the necessary spare parts to support operations for the avionics suite for 45 days. If that fighter contained avionics with removal rates equal to those of today's F-15, such a strategy would require \$1.3 billion,³ almost three times the current investment in F-15 test equipment and avionics spare parts. Such a step would probably not be affordable and, more

important, would not surmount the fault-isolation problem described below.

The task of ensuring the readiness of future fighter aircraft takes on a different perspective, however, when their problems are not driven by contemporary removal rates. For example, if on our next fighter aircraft we achieved a four-fold improvement in mean-time-between-removals (MTBR) in just 11 Line Replaceable Units (LRUs), the total required investment in test equipment and spare parts would be only \$450 million.⁴ It turns out that those 11 LRUs, which represent about 10% of the number of avionics LRUs on a modern tactical fighter, comprise the subsystems most important to combat mission success: the radar, the inertial navigation system (INS), the head-up display (HUD), and the weapons delivery (WD) computer. Achieving such an improvement in MTBR will require improvements not only in the reliability of the components but also in their fault-isolation characteristics.

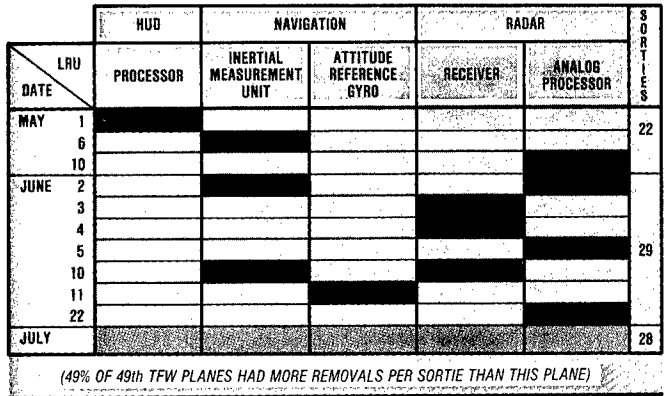


Figure 2: Removals from Plane 7133 (F-15).

Figure 2 illustrates reoccurrent removals as one indication of the current fault-isolation problem.⁵ The chart is a history of removals from a single F-15 from the 49th Tactical Fighter Wing at Holloman Air Force Base for a three-month period in 1980. To use the radar as an illustration, note that the analog processor was removed and replaced on May 10 and again on June 2. On June 3 and again on June 4 the receiver was removed and replaced, and on June 10 the receiver was pulled. On June 22 the analog processor was removed and replaced once again. One way to interpret the sequence of events is that during the month of June the aircraft, even though it flew 29 sorties, lacked a dependable, combat-capable radar, which is necessary for the F-15's unique combat responsibilities.⁶

Many people argue that the solution to such problems is to reduce the sophistication and complexity of our weapon systems. Those arguments are largely misguided. Many Air Force missions today *require* higher levels of sophistication than previously was the case: The newer systems must perform more functions, they must perform them with greater precision, and they must rely on more integration among functions. Although it is always useful to examine requirements statements to eliminate demands for unnecessary sophistication, it is a fact that for certain missions, all levels of *effective* functional performance require sophisticated equipment. For example, the interception of low-flying, hard-to-detect Soviet bombers and cruise missiles requires sophisticated radar, fire control, and weapon capabilities. Achieving desirable reliability and fault-isolation capability in such equipment requires a special developmental process.

The fact that it has been done before makes us believe that changes in the development process can lead to improvements

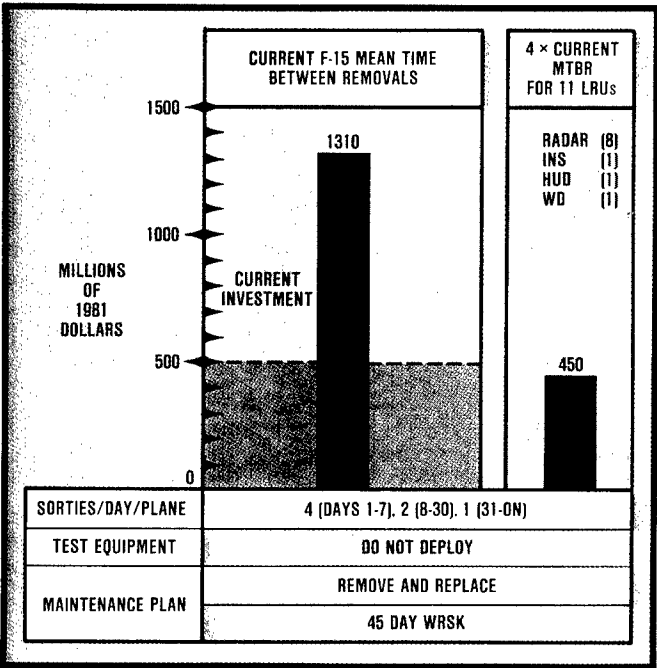


Figure 1: Avionics Procurement Costs for Test Equipment and Space LRUs (18 Combat Squadrons; Excludes Electronic Countermeasures Equipment).

in removal rates of sophisticated avionics equipment. The Minuteman I guidance system and the Carousel inertial navigation system (Table 1) have both achieved excellent removal rates. Although they had very high removal rates after their initial development cycle, both underwent additional cycles to increase their availability by improving their reliability and fault-isolation characteristics. In each case, the improvement was fifteen-fold. By comparison, the F-15 inertial navigation system, which operates in a much more demanding environment and in many more modes, has undergone only *one* development cycle. Its MTBR is short and has not improved over time.

	MINUTEMAN I GUIDANCE	CAROUSEL INS	F-15 INS
DEVELOPMENT CYCLES	2	3	1
MTBR (1 HR) AFTER 1st CYCLE	600	100	75
2nd CYCLE	9000	500-600	—
3rd CYCLE	—	1500	—

COMPARISON OF INERTIAL SYSTEM DEVELOPMENTS
TABLE 1

The key, we believe then, is to make more than one pass through the development cycle. This is necessary because a developer cannot use engineering or reliability theory to predict adequately where and how often failures will occur. One development cycle, including realistic operational testing, is needed to identify significant failure modes. A further cycle is required to reduce failure rates to acceptable levels and to develop an adequate fault-isolation capability.

We call such a strategy *maturational development*.⁷ Although time-consuming and costly, it need not delay the introduction of new weapon systems into the inventory. If the development of critical subsystems were allowed to begin *before* (instead of after) the development program for the weapon platform, multiple development cycles could be completed in time for incorporation of the mature subsystem in the full weapon system. Because of the investment in time and money required for maturational development, the resulting hardware should have application across a number of weapon systems. The existence of mature, widely applicable building blocks would thus permit the introduction of many modular functional performance improvements.

As often demonstrated, the problems of subsystem integration at the full weapon system level require a similar approach. It is evident, however, that this too would require a significant change in the way most weapon system programs are managed. Figure 3 shows the testing and production schedules for five fighter aircraft developed by the United States Air Force under varying acquisition philosophies during the 1960s and 1970s. The dots on the test program bars indicate when a high-rate production decision was made (DSARC IIIB or its equivalent). In each of the five programs, that decision occurred well in advance of the end of testing (and often before the onset of the operational test and evaluation phase). Please note also that by the time testing was concluded in each program, assuming a period of adequate feedback of the results, a substantial number of aircraft had already been delivered into the field. In almost every case, substantial deficiencies that degraded the operational effectiveness of the aircraft were identified late in

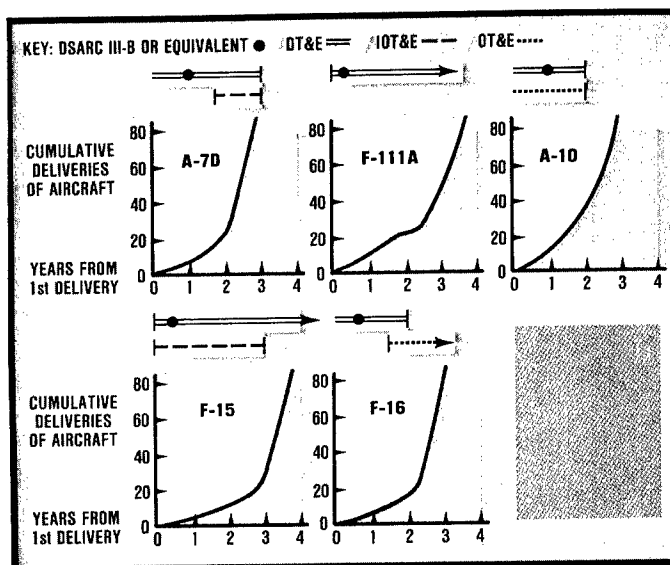


Figure 3: Testing and Production Schedules of Five Recent Tactical Aircraft Programs.

the test program or early in operational use. In those cases, however, so many aircraft had been delivered to the field that the Air Force chose to accept the degraded performance rather than incur the great expense of retrofitting the required changes.

What is needed is a new way of managing the transition from development to production at the major system level. To ensure the prompt identification, feedback, and correction of problems, such an approach requires the sensible use of prototypes during both advanced and full-scale development, and strong incentives to exploit available mature building blocks. Under such a strategy, there would be no delay in beginning production; but production would continue at a low rate until intensive and realistic operational testing could be accomplished and used in the design process. Only then would a system go into full production. We believe that such an approach, especially when combined with maturational development of the critical subsystems, will then yield weapon systems with high levels of functional performance and combat forces with vastly improved readiness. We should do no less.

*This article draws on research sponsored by the U.S. Air Force and performed at the Rand Corporation. Special credit is due Hy Shulman, Jean Gebman, and I. K. Cohen.

NOTES

¹Support policies, procedures, and organizations also have an important effect on the readiness levels achieved by sophisticated weapon systems. For a discussion of how support policies, procedures, and organizations that are especially adapted to the future's intense and rapidly changing warfighting environment can enhance readiness, see Michael D. Rich and Stephen M. Drezner, *An Integrated View of Improving Combat Readiness*, The Rand Corporation, N-1797-AF, February 1982, pp. 7-18.

²See Donald E. Emerson, *An Introduction to the TSAR Simulation Program: Model Features and Logic*, The Rand Corporation, R-2584-AF, February 1982; Richard J. Hillestad, *Dyna-METRIC: A Mathematical Model for Capability Assessment and Supply Requirements When Demand, Repair, and Resupply Are Nonstationary*, The Rand Corporation, R-2785-AF, June 1982. Both models are widely used in the Air Force.

³These estimates are expressed in 1981 dollars.

⁴Research, Development, Test, and Evaluation costs are excluded from both calculations.

⁵This term should not be confused with "recurrent removals," which the Air Force uses to describe removals that recur within three flights, or "repeat removals," used to describe those that repeat after the next flight.

⁶We also have observed similar patterns on other modern tactical fighters.

⁷For details, see J. R. Gebman et al., *The Need for a Maturational Phase During Avionics Development*, The Rand Corporation, forthcoming.

Corrosion: A Formidable Air Force Enemy

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Abstract

A constant fight is underway in the Air Force to prevent and control the corrosion which attacks the metal components of all weapons systems and support equipment. In this discussion, a former manager of the Air Force Corrosion Program seeks critical management support for the program through descriptions of the types of corrosion, recent successes, and projections for the future. The author supports his personal knowledge and experience with the findings and opinions of experts in the Department of Defense and industrial corrosion communities.

Introduction

The Air Force confronts a major enemy every day within its own ranks—corrosion. This powerful force is Mother Nature's method of gradually returning metals to their natural ores when they react to her environment; for example, unprotected iron in the presence of moist air converts to rust or iron oxide, the natural state of iron. Unguarded aircraft, missiles, vehicles, and support equipment quickly fall prey to this insidious and unrelenting enemy. If it gets out of control, it can not only destroy structural integrity and the safety of operating systems but also require expensive repairs and modifications to keep valuable Air Force assets in operation through their normal and often extended lifespans.

General Bryce Poe, former commander of the Air Force Logistics Command, told a Tri-Service Corrosion Conference in November 1980 that he could use the billion dollars spent every year in fighting corrosion to fund one-third of the Air Force's shortfall in aircraft replenishment spares for fiscal year 1981 (1:1). The scarcity of Air Force logistics and acquisition dollars and the startling numbers of Soviet weapons threatening world peace demand utmost attention and effort toward minimizing corrosion damage. It is a matter of conserving Air Force resources and thereby making more money available for expansion and support of those resources. Although the diverse tactics of this longstanding enemy are difficult and expensive to contain and past losses to the foe have been extremely serious, Air Force logistics, research and development, and acquisition personnel have rapidly gained ground against this indiscriminate and ruthless attacker.

Nature of the Enemy

Successful waging of war requires thorough knowledge of the enemy and his capabilities, and Air Force "intelligence" reveals that corrosion takes various forms in attacking critical and expensive warfighting resources: uniform, pitting, intergranular, galvanic, crevice or concentration cell, stress and fatigue cracking, and filiform (2:24-26) (13:2-6). Classification of corrosion is usually based on the nature of the corrodant (liquid or gas), the mechanism of corrosion (electrochemical or direct chemical reactions), and the

appearance of the corroded metal (corrosion is uniform over the surface or localized in small areas only) (13:2). In classifying corrosion by appearance, one must distinguish between macroscopically localized corrosion and microscopic local attack. In the latter, only a small amount of metal is dissolved and the corrosion rarely spreads beyond the structural weakness which causes it. With this form of corrosion, considerable damage can occur before the problem becomes visible to the naked eye. With the microscopic forms, such as pitting, the corrosion may begin at a structural defect, but it grows by corroding "good" material. In the war against corrosion, as in all wars, one must first understand the major types of corrosion attack and methods used by the Air Force to counterattack the enemy.

Uniform attack occurs over the entire surface of a metal. It is relatively slow acting and is commonly seen in the tarnishing or dulling of brightly polished metals, such as aluminum, silver, copper, and nickel. It can be wet or dry, electrochemical or chemical. Proper selection of metals and use of adequate coating systems, such as painting and plating, can prevent this common and easily detected type of corrosion.

Pitting, a slow, destructive, and often hidden localized attack, can completely penetrate a metal or alloy and cause unexpected failures. It appears as white or gray powdery deposits on aluminum and magnesium and as tiny dark holes in steel surfaces, particularly stainless steel. When lightweight metals prone to pitting must be used in constructing aircraft and support equipment, the best protection is durable coating systems, frequent cleaning, and use of chemical conversion coatings and corrosion-inhibiting sealants.

Intergranular corrosion concentrates on the boundaries of the natural grains of a metal or alloy. It has a sugary texture caused by loose grains and often presents a rough appearance to the naked eye. It attacks the base metal adjacent to grain boundaries of alloys because more noble metals are concentrated in these areas (for example, copper is 2024 aluminum alloy); and, for this reason, it usually results from improper heat treatment. *Exfoliation*, a special and advanced form of intergranular corrosion, begins on the clean surface of an aluminum alloy but spreads below it to lift off the surface grains. The attack has a laminated, flaky, or blistery appearance; and whole layers of material are eaten away in a pattern that resembles the pages of a book or a deck of cards. Intergranular corrosion, including exfoliation, can be prevented through proper heat treatment or tempering, use of a modified alloy, and shot-peening heavily machined extrusions and forgings to close off the ends of grains exposed by the machining process.

Galvanic or dissimilar metal corrosion results when metals or alloys with naturally different electrochemical potentials (chemical activities) come in contact with a conductive solution. For example, the electrochemical difference between carbon and zinc causes the zinc case of a dry-cell

flashlight battery to corrode as current flows through a wet paste from the zinc to the carbon center post. When metals with incompatible chemical characteristics must be selected, corrosion-inhibiting sealants or other barrier materials should be used to isolate the metals from each other.

Crevice or concentration cell corrosion can occur under bolt and rivet heads, under gaskets, between joining or faying surfaces of metal panels, or even under soil deposits or corrosion residue on metal surfaces. Obviously, this self-sustaining variety of corrosion is difficult to detect. Crevice corrosion is common to such metals as stainless steel, aluminum, and titanium, which depend on an air-formed oxide film to resist corrosion. Alloying, frequent washing and rinsing of equipment, and use of a corrosion-inhibiting sealant between faying surfaces and around fasteners before installation eliminate crevices and the potential for corrosion.

The serious problem of *stress corrosion cracking* can occur in most alloys, including aluminum, magnesium, high-strength steels, and stainless steels when they are subjected to corrosion and constant tensile stress either instilled internally during cold work, welding, or heat treatment or applied externally during service. It can be prevented by relieving stresses, applying durable protective coatings, selecting more resistant materials or tempers of the same material, or by shot-peening to induce a compressive stress on the metal surface to offset tensile loading. *Corrosion fatigue*, a special form of stress corrosion cracking, results when a part is subjected to external cyclic stresses after corrosion has reduced its fatigue limit. Failures caused by corrosion fatigue often occur in structures subjected to continued vibration. This type of corrosion usually appears as several smaller cracks branching out from the failure crack. Although little is known about corrosion fatigue, stress-relieving heat treatment and shot-peening of parts reduce failures from corrosion fatigue by limiting opportunities for fatigue cracks to start.

Filiform corrosion produces threadlike filaments when water and oxygen are trapped under organic coatings or paints at edges of cracks, nicks, or scratches in the coatings. A sound protective coating that keeps the part dry prevents this type of corrosion.

Aircraft and equipment consisting of a vast array of metals and alloys employed in numerous intricate designs present countless opportunities for corrosion. The tasks of preventing corrosion through proper design and materials, selecting surface coatings, and treating and controlling corrosion that occurs despite preventive efforts are major challenges to Air Force engineers and maintenance managers.

An Expensive Battle

Direct and indirect expenses incurred in the battle against corrosion are phenomenal. A study by the National Bureau of Standards in 1975 estimated that corrosion, each year, costs the U.S. economy \$70 billion, the federal government \$8 billion, and the Air Force \$1 billion. The study concluded that use of current technology could prevent 15 to 20% of the losses (3:41). The Air Force pays direct costs of corrosion in the following areas:

- Manpower in corrosion facilities
- Engineering and staff personnel
- Nonproductive equipment downtime
- Equipment and supplies used in corrosion prevention and control

- Construction of corrosion facilities
- Data
- Training
- Cleaning and inspection of aircraft and equipment
- Removal of equipment and panels to allow inspections
- Repair or removal and replacement of corroded components
- Chemical treatment, priming, and painting of metals and alloys (4:21)

Aircraft downtime and additional aircraft needed to perform the mission reflect indirect costs of corrosion. Although obsolescence has a greater impact on the lifetime of aircraft in service than corrosion, downtime caused by corrosion increases redundant aircraft by an estimated 5 to 8%. The yearly capital redundancy cost for Air Force, Navy, and Coast Guard aircraft is almost \$2.4 billion (3:44).

Repair of corrosion damage incurs heavy costs for depot overhaul and field-level maintenance of aircraft, ground support equipment for aircraft, and communications vans and shelters. Warner Robins Air Logistics Center estimates that approximately 28% of the costs for C-130 fleet maintenance and 23% of the costs for C-141 fleet maintenance are due to corrosion (5:6). Refurbishment of corroded electrical quick disconnects on F-111 crew modules during programmed depot maintenance at Sacramento Air Logistics Center requires an average of 160 man-hours per aircraft (6:35). And the center also devotes approximately 90% of the depot repair work on communication vans and shelters to corrosion. More than 180 people in the van shop expend 20,000 man-hours in this role at a cost of almost \$8 million per year (1:4). In 1981, three unused AN/GPN-22V ground-approach radar units received extensive refurbishment at a cost of approximately \$222,000 each as a result of corrosion caused by designed-in problems and inadequate preservation while the units were in storage. In addition to these in-house efforts, depots and major operating commands have numerous contracts for corrosion treatment and prevention, as well as research and development. For example, a current contract with a Hong Kong firm for depot-level corrosion work in C-130 aircraft assigned to Pacific units calls for more than 5,000 man-hours per aircraft at a unit cost of approximately \$183,000.

The cost of redesigning and remanufacturing aircraft and support equipment with less corrosion-prone materials is astounding. During 1975 alone, corrosion rework and prevention treatment in the latrine area on the C-141 fleet cost \$22,000 per aircraft. Redesign and remanufacture of landing-gear assemblies for KC-135 aircraft to replace corrosion-prone 7075-T6 aluminum and magnesium cost the Air Force more than \$73 million. Another \$5 million was spent in changing 4340 steel to 300M steel on main landing gears of C-141 aircraft to eliminate dangerous problems caused from stress corrosion cracking.

These are only a few examples of the tremendous costs of corrosion work. In most cases, however, it is difficult to put price tags on corrosion and separate man-hours and dollars expended for its prevention and control from total maintenance and repair costs. Data collection systems for Air Force maintenance in the past did not permit accurate and comprehensive determination of costs stemming from corrosion. Therefore, devising a method to obtain more usable corrosion cost data is only one of many important lines of attack recently undertaken by corrosion combat forces.

Forces and Strategy

To keep the upper hand in this expensive war, the Air Force requires awesome forces and well-planned strategy. The forces are located throughout the research and development, acquisition, and maintenance communities; and the strategy is outlined in a few directives and numerous technical orders. Warner Robins Air Logistics Center has had full management responsibility for the corrosion program since October 1979. Prior to that time, Headquarters USAF was responsible for the program, and Warner Robins Air Logistics Center, as manager of the AFLC corrosion program, was the primary corrosion management organization. AFR 400-44, *Air Force Corrosion Program*, governs the program and delineates the responsibilities of numerous agencies; but it does not include policy for corrosion prevention and control of real property and equipment installed on the property. AFR 91-27 assigns these responsibilities to the Air Force Civil Engineering Center at Tyndall Air Force Base, Florida. General technical orders 1-1-1, 1-1-2, and 1-1-8, as well as corrosion manuals for specific systems and equipment, contain detailed procedures for cleaning aircraft and equipment, treating corrosion, and painting. Although each using command develops its own implementing directives, AFR 400-44, the management bible for the corrosion program, contains the prevailing guidance for employing friendly forces against the corrosion foe.

AFR 400-44 assigns responsibilities for corrosion control to all operational commands, Air Training Command, Air Force Systems Command, and Air Force Logistics Command. These agencies work in concert to accomplish the two principal objectives of the program—preventing corrosion on new systems, equipment, and components and minimizing the impact of corrosion on existing resources. Operating or using commands conduct field-level programs concerned with planning, budgeting, training, and evaluation; and they use authorized equipment and supplies to prevent and treat corrosion in accordance with current technical orders. The Systems Command conducts research and development programs on new and improved materials and processes for preventing and controlling corrosion; develops standards and specifications for these materials and processes; and evaluates new products, processes, and equipment for use in the field. The command also works with gaining commands for new equipment to ensure that contractors comply with pertinent standards, specifications, and handbooks and with the advice of corrosion advisory boards during system design and acquisition. Air Training Command provides specialty training for field-level corrosion technicians. The Logistics Command provides policy guidance and technical data, performs depot-level corrosion work, furnishes engineering support to using commands, and coordinates R&D needs and lessons learned with the Systems Command. It also evaluates the effectiveness of major command programs, proposes and implements modifications of equipment, solves corrosion problems, cross-feeds information of interest throughout the corrosion community, and coordinates the Air Force program with the programs of other services and allied nations (7).

Successful Campaigns

Well-equipped and highly skilled forces have successfully employed their strategy in numerous campaigns ranging from improvements in program management to major

breakthroughs in technology. One example involves mandatory standards for system design. Since the mid-1970's, MIL-S-1568, *Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems*, has been required guidance for manufacturers in selecting materials and processes to minimize corrosion on new equipment.

Also in the areas of prevention are advisory boards established for every major weapon system under development. These boards include corrosion experts from the Air Force Logistics Command (Acquisition Logistics Division and the prime depot for the system), the gaining command, Air Force Systems Command (Materials Laboratory), and manufacturers. The boards advise system program officers on the selection of materials and criteria for designing corrosion resistance in systems under development. The boards base their advice largely on state-of-the-art technology and lessons learned from previous systems. Although board membership changes somewhat after a system becomes operational, the boards continue to deal with corrosion problems that inevitably slip through the design phase or show up later for other reasons.

In a major move to ensure well-equipped facilities for corrosion work, the Air Staff adopted the Corrosion Prevention and Control (CPC) Facilities Plan in 1979. The specific purpose of the plan is to organize and rank order all Air Force needs for construction and modification of corrosion facilities to justify monies in support of those needs to Headquarters Air Force, the Office of the Secretary of Defense, and Congress. The Deputy Chief of Staff for Logistics at Headquarters AFLC leads a panel to implement the plan; and members of the panel represent all major operating commands, as well as the Air Force Corrosion Program Management Office at Warner Robins Air Logistics Center. Implementation of the CPC Facilities Plan is, without a doubt, one of two major innovations in program management during the past five years.

The second major innovation was creation of the Joint Logistics Commanders (JLC) Panel on Corrosion in 1980 to promote coordination of corrosion technology, training, and publications among Army, Navy, and Air Force agencies. With subpanel membership from each service and a broad charter signed by the logistics chiefs of each service, the JLC Panel has proven very worthwhile in preventing duplication of efforts and reducing costs and man-hours. Its merits lie mainly in the fact that it is a dynamic cross-feed mechanism with patronage at the level of the four-star general officer.

Another valuable cross-feed mechanism is the corrosion program survey conducted at all major commands. Every three or four years, a team of 6 to 10 experts from Logistics Command, Systems Command, and headquarters of the host command survey a sampling of bases, aircraft, and equipment assigned to each command and evaluate program management in the command. Led by representatives from the program office at Robins Air Force Base, the team then presents formal briefings to general officers at the headquarters of surveyed commands, provides written survey reports, and conducts follow-up action on items assigned to various agencies that support the command's corrosion efforts. The status of follow-up action on assigned items is reported semiannually to the headquarters of surveyed commands and disseminated quarterly to other commands in the *Corrosion Summary*.

The *Corrosion Summary*, published by the AFLC Corrosion Program Officer at Warner Robins Air Logistics Center for

several years, has been a significant source of information about corrosion. Recent efforts have aimed at broadening the content of the summary to include more inputs from commands other than Logistics Command. Currently, the summary provides information on corrosion technology, training, symposia, and successes to numerous Air Force, Army, Navy, Marine, Coast Guard, and allied military agencies.

Although Air Force and other military units can and do share technology, training, and data, their corrosion problems are not standard or even similar in many cases. Since rates of corrosion depend largely on such environmental factors as weather, atmospheric pollutants, and geography, each Air Force installation experiences distinct corrosion problems based on these factors. A contract study (Pacer Lime) completed by Michigan State University in 1981 provides useful information on the relative severity of corrosion at Air Force installations throughout the world. Corrosion program managers use this information to determine the need for corrosion repair over given periods, to schedule aircraft and equipment washing and painting, and to man and equip corrosion shops.

In the battle of technology versus Mother Nature and corrosion, the Air Force has won important victories in the areas of protective coatings, selection of materials, and modification of aircraft and equipment. Not long ago, many USAF aircraft, including the C-130 and the C-141, were unpainted as a rule. And manufacturers frequently used the highly corrosion-prone 7075-T6 and 7178-T6 aluminum alloys because of their high strength-to-weight ratios. Extensive use of these alloys throughout the wings of the C-130 led to severe corrosion problems on the upper surfaces of wing panels in the early sixties. Starting in 1969, the entire center wing sections of all C-130Bs and subsequent models in service at the time had to be replaced because of corrosion damage; the total cost of replacing these sections was approximately \$113 million (12:1). In early 1974, all aluminum alloy components of the C-130 wings were changed to the corrosion resistant 7075-T73 alloy for new production aircraft. In early 1970, the upper surfaces of wing panels of the C-130 fleet received a corrosion inhibiting elastomeric coating system. The upper surfaces of wing panels of the C-141 fleet received this same coating in mid-1974 because of similar corrosion problems. These changes have virtually eliminated corrosion on the upper surfaces of C-130 and C-141 wing panels.

In the mid-sixties, the C-130 and C-141 fleets received state-of-the-art acrylic nitrocellulose lacquer on their exterior surfaces; and an improved epoxy primer and aliphatic polyurethane topcoat system was applied to these aircraft in the early seventies. The presently used corrosion inhibiting polysulfide primer and aliphatic polyurethane topcoat system was applied to the C-130 in early 1975 and to the C-141 in late 1977. This system effectively reduces the possibility of intergranular attack and stress corrosion on the exterior surfaces of aircraft because of its built-in corrosion inhibitors and its capacity to bend without cracking as the surfaces of the aircraft flex during flight. This improved protection against corrosion of exterior surfaces combined with better sealing techniques for pylon-to-wing attachment fittings has extended the programmed depot maintenance cycle for the C-141 from three to four years and has saved 25 to 30% on annual depot maintenance costs (5:4).

In addition to developing better aircraft coatings, many depot system managers have developed aircraft paint scoring

techniques to determine more accurately when aircraft must be repainted. Most managers use grid systems to divide each aircraft into sections and then assign numerical ratings to each section depending on the condition of the paint. Weighted factors (depending on structural criticality of the areas) are used to derive a final score. If the score is above a certain predetermined cutoff point, the aircraft is scheduled for repainting.

Improvements in paint systems have not been limited to aircraft only. Extensive testing of coating systems for ground-support equipment, powered and nonpowered, has led to selection of zinc-rich primer/polyurethane topcoat as the Air Force standard for steel equipment and epoxy primer/polyurethane topcoat as the standard for aluminum or magnesium equipment. And revision of MIL-S-8512, *General Specification for the Design of Special Aeronautical Support Equipment*, has alleviated such designed-in corrosion problems as lack of drain holes and inadequate plating (12:15). As the responsible agency for most aircraft ground support equipment, the San Antonio Air Logistics Center provides corrosion lessons learned to the Acquisition and Logistics Division and to the Systems Command for consideration in designing new support equipment.

Numerous corrosion problems in the past have been the result of inattention to the chemical makeup of lubricants, sealants, and other nonstructural materials used on Air Force weapon systems, support equipment, and vehicles. Many lubricants once used on Air Force equipment contain graphite, and graphite is cathodic to other metals (electrochemical current and metal ions flow to it from other metal anodes). Even a pencil marking on an aircraft surface can lead to exfoliation corrosion. And many common aircraft silicone sealants contribute to corrosion because they emit acetic acid as they cure. The Air Force now prohibits use of graphite lubricants and silicone sealants that emit acetic acid. And polyvinyl chloride (PVC) is another culprit that has recently been banned on Air Force equipment. This plastic-like material has been used routinely as insulation for wiring and on other aircraft and support components; but mild heat, aging, and ultraviolet rays deteriorate the PVC compound. The hydrogen chloride gas liberated during the deterioration process readily reacts with moisture in its surroundings to form corrosive hydrochloric acid (8:26). Although it is prohibitively difficult and expensive to remove all existing PVC material from Air Force equipment, established procedures now prohibit its use on new equipment and require its removal from existing equipment on an attritional basis.

The experts have banned use of graphitic lubricants, sealants that emit acetic acid, and wiring coated with polyvinyl chloride; but they have pushed for increased use of spray-on or brush-on compounds that displace water. These compounds retard corrosion very well, and maintenance personnel with no special skills can use them. One of the most widely used compounds in the Air Force is AMLGUARD, which was developed by the U.S. Navy for temporary protection on carrier-based aircraft when painted surfaces were chipped or worn away and existing moisture precluded repainting (9:1). Such compounds are particularly useful on Air Force aircraft, since an aerosol spray paint suitable for touch-up of polyurethane finishes has not yet been developed.

Perhaps the most significant strides against corrosion have been made in redesigning and remanufacturing the latrine and galley systems in cargo aircraft. Corrosion generated by spillage or leakage in these areas causes numerous plumbing

and servicing problems on both military and commercial aircraft. But joint efforts of aircraft system managers, ALC corrosion managers and engineers, and Military Airlift Command have brought a number of major improvements. For example, the fiberglass shop managed by Military Airlift Command at McGuire Air Force Base, New Jersey, has produced fiberglass latrines for the C-141 aircraft; and portable laboratory units are now manufactured under contract for both C-130 and C-141 aircraft. These new facilities represent major improvements that will drastically reduce corrosion damage in latrine areas.

The Air Force Corrosion Program has achieved numerous successes in the past, both in program management innovations and application of advanced corrosion technology. Well-organized forces and constant improvements in strategy have blocked the infiltration of corrosion forces in thousands of areas. And the advance of corrosion in many other areas has been stopped or slowed significantly through vigorous countermeasures, such as repair, redesign, application of coating systems, regular inspection and cleaning of equipment, and removal of materials that cause corrosion. Air Force combatants against corrosion must work even harder in the future to obtain optimum mission performance and system longevity from increasingly complex and expensive weapon systems and support equipment.

Future Containment

Significant future containment of corrosion will depend largely on the effectiveness of preventive measures, early detection and evaluation, and quality techniques of treatment and repair. Increased emphasis on prevention of corrosion through proper design and choice of materials and finishes is a priority consideration. Prevention is much less expensive than necessary follow-up actions. For example, repair of corrosion and structural damage to C-130 aircraft wings has cost more than the original purchase price of the wings. When corrosion requires major modifications in large numbers of aircraft, the cost can amount to hundreds of millions of dollars (10:13). Management and engineering decisions to use a corrosion-prone alloy because of its slightly higher strength, lighter weight, or lower initial cost must consider the life-cycle costs that result from designed-in corrosion problems. The cost of corrosion must be incorporated into the costing model, and accurate projections for mistakes in the design and selection of materials must be available to justify use of less corrosion-prone materials and better designs despite higher initial costs. To provide these cost figures, the Air Force corrosion community must develop much better methods for determining the cost of corrosion on existing systems and equipment. It must vigorously pursue initiatives through AFLC channels for a life-cycle cost element and an improved system for collecting cost data. Furthermore, advisory boards for preventing corrosion must be established as early as possible in the validation phase of system acquisition, and system program managers must carefully consider board recommendations in view of potential long-term savings. This is the only way to ensure application of lessons learned rather than reinvent the wheel on every new weapon system.

Expanded use of nondestructive inspection (NDI) techniques is the best approach to early detection and evaluation of corrosion. In the past, necessity dictated visual detection of most damage from corrosion, but this method involves countless man-hours in removing panels and components to gain access to the area of inspection. Nondestructive inspection has not been used because of its emphasis on finding potentially damaging cracks and its general ineffectiveness in revealing hidden corrosion. For various reasons, x-ray, eddy current, fluorescent penetrant, and magnetic particle techniques are basically useless in corrosion detection. But ultrasonic, acoustic emission, low-frequency eddy current, and neutron radiographic techniques offer considerable promise. The Air Force Corrosion Program Management Office has established a project with the Air Force Materials Laboratory to examine existing NDI tools and potential future methods of detecting and evaluating hidden corrosion damage (11:4). This is a long overdue step that should yield significant benefits in future years.

Finally, containment of corrosion will require greater management concern for corrosion problems and increased attention to maintenance corrosion training and quality control. These needs apply across the board to field-level, depot-level, and contract maintenance organizations that have been too prone to place concern for corrosion on the back burner. Maintenance personnel must know how to identify corrosion and how to repair damage caused by corrosion in keeping with the best methods set forth in current technical orders.

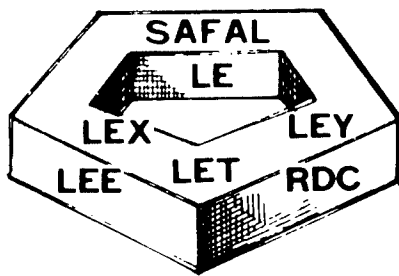
The Air Force's battle against its in-house enemy is neither easy nor cheap, and it is a battle that can never be completely won. But it is a battle that must be fought with zeal and determination if the Air Force expects to accomplish its difficult mission with fewer weapons and dollars to operate and maintain them. Since most of the older weapon systems were developed with performance rather than long service life as the primary consideration, Air Force people must live with many designed-in corrosion problems. But we are gaining ground on these problems, and will continue to do so, through improved program management, use of corrosion-resistant materials, application of more effective coating systems, and modification of corrosion-prone areas of aircraft and equipment.

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"The day when nobody comes back from a war it will be because the war has at last been properly organized."

Boris Vian in
Peter's Quotations



USAF LOGISTICS POLICY INSIGHT

Spares To Be Examined

The Air Force Chief of Staff directed that a study group be formed to improve the aircraft replenishment spares (BP1500) budget forecasting process. The group will examine all factors bearing on the requirements determination/forecasting process and how they affect the funding of replenishment spares in support of operational needs.

Phase IV On Target

The Base Level Data Automation Program (Phase IV) will replace the current UNIVAC 1050-II and Burroughs 35/37/4700 computers providing base level logistics support. Phase IV is nearing a critical milestone. A systems acquisition approach was selected for the Phase IV Program whereby contractors would compete in a "compute-off" for the implementation contract award. In December 1980, contracts were awarded to Sperry UNIVAC and Burroughs Corporation to transition high risk data systems to their proposed hardware. The program is proceeding well, aimed toward a production decision in early 1983. Phase IV systems installation/conversion will begin in mid-1983 with Langley AFB as the lead base and will be completed in late 1985.

Energy Plan Pushed

The Air Force is continuing on an aggressive energy program. The Deputy Secretary of Defense urged the Services to promote energy conservation as a major priority. There is a large potential to save energy and strengthen our defenses and our economy. Energy conservation involves research and development, improvements to system efficiencies, and energy awareness. The Air Force Energy Plan published in October 1982 describes the various initiatives the Air Force is undertaking in support of OSD and national energy goals. The Committee on Appropriations has approved all funds requested in FY83 for energy conservation and urges DOD to request the resources necessary to achieve its 20% facility energy consumption reduction goal by 1985. Energy conservation policy was established as an Air Force major priority item in Air Force Energy Program Policy Memorandum 82-3, 2 June 1982, by the Deputy Director, Maintenance and Supply (HQ USAF/LEY).

Federal Acquisition Regulation Directed

The contracting functional area will undergo a major change as the Federal Acquisition Regulation (FAR) is implemented throughout the Federal Government effective 1 October 1983. Under development since 1978, Executive Order 12352 directs completion of the FAR by the end of calendar year 1982. During 1983, both defense and civil agency councils will complete an executive review of the new regulation. Final publication, familiarization, and training will precede the October 1983 effective date. It is anticipated that some degree of Defense and Air Force supplementation to the FAR will be necessary.

Industrial Modernization Encouraged

DOD is drafting guidance which will establish an Industrial Modernization Incentives Program (IMIP). The IMIP goal is to develop incentives and reduce impediments to encourage investment by defense contractors which will result in productivity increases benefitting both the DOD and contractors involved. IMIP targets industry through contractual and other incentives to substantially increase private capital investment for modernization to enhance production efficiency.

TO 25 ►

Management Overview: Logistics Capability Measurement System (LCMS)

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Background

With the drawdown of forces and defense budgets in the years following the Vietnam Conflict, the USAF experienced a period of underfunding for logistics resources. One of the most significant problem areas involved the funding of replenishment spare parts. This logistics resource category includes all of the higher cost assemblies and subassemblies required to keep individual aircraft operationally ready. As these items fail, they must be repaired at base or depot level; or if not economically repairable, they are condemned and discarded. Stocks of these items must be maintained at base or depot level to replace failed items that are condemned or placed in the repair cycle. These "stockpiles" have traditionally been divided into two categories: (1) those items used to support the everyday peacetime flying program (peacetime operating stocks) and (2) those items set aside for potential wartime use (War Readiness Materiel).

Because of the lack of sufficient funding during the late seventies, these stocks were drawn down to low levels. This resulted in decreased numbers of mission capable aircraft and decreased ability to sustain the forces, should they be required to fight.

To some extent, this erosion of the spares support base took place due to our inability to directly and objectively assess the relationship between congressional funding levels and aircraft readiness. Consequently, many logistics programs were partially crowded out of the budget each year by more "glamorous" system development or system procurement programs. Alarmed at the apparent readiness and sustainability problems in defense, Congress directed the services to develop the capability to illustrate the relationship between readiness and funding of logistics programs. During this period, the USAF was developing two computer models designed to provide both peacetime and wartime capability assessments related to the spares procurement and maintenance budgets. With the growing emphasis and concern for readiness and sustainability generated by both defense officials and Congress, the Logistics Capability Measurement System (LCMS) evolved from theory to important application.

Logistics Capability Measurement System (LCMS)

The objectives of the LCMS are:

- (1) Assess, by aircraft model, type, and series, the logistics capability to meet assigned wartime missions.
- (2) Support programming and development of logistics resource budgets to accomplish these assigned missions.
- (3) Assess the impact on readiness and sustainability of unprogrammed flying hour surges, budget changes, or drawdown of materiel assets to support unforeseen international crises.
- (4) Evaluate alternative resource allocation strategies.

System Description

LCMS is comprised of two computer models, each of which contains several specialized modules. One model is designed to support analyses of our peacetime posture and the manner in which planned peacetime flying programs and budgets affect our readiness levels. The other model looks at our ability to sustain forces in wartime. The relationship is illustrated in Figure 1. Following is a brief description of each model.

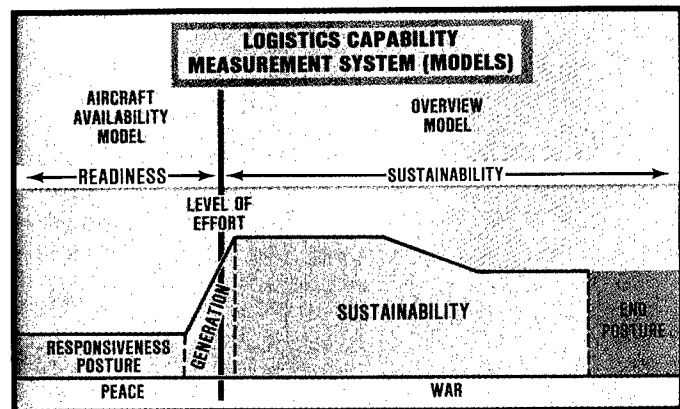


Figure 1.

Aircraft Availability Model (AAM):

A generalized diagram of the inputs and outputs of the AAM is shown in Figure 2. The primary input data are: (1) programmed *peacetime* flying hours per year by type, model, and series of aircraft over the five-year programming period and (2) selected historical and statistical data on the use of spare parts (assemblies and subassemblies). The item data base contains information on approximately 130,000 individual repairable items. The primary data elements used from this data base are historical failure rates, condemnation rates, unit cost for procurement and repair, and application information; e.g., which aircraft types use the assembly and how many are required.

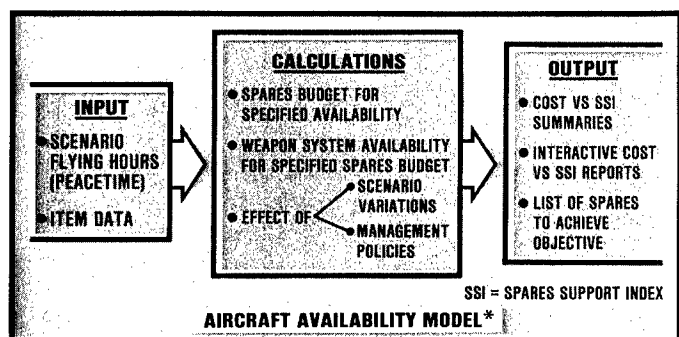


Figure 2. * Logistics Management Institute (under contract to support LCMS)

Through a series of highly complex statistical computations, the model determines an appropriate mix of procurement and repair funding for each year to attain specified levels of aircraft system availability and identifies the specific spares that need to be purchased to achieve this level of support. The model has some interactive features which allow the user to enter "target availabilities" and get cost estimates as output or, conversely, enter proposed budgets and get availability estimates as output. The model applies a form of marginal analysis when generating outputs which assures the greatest marginal return on availability for budget changes under consideration.

The primary application of this model by the Air Staff is in development of programs and budget estimates for the spares procurement program. The model has enabled the Air Staff to vastly improve estimates of the *cost* of achieving desired levels of availability and has been highly successful in providing Congress with estimates of the likely outcome of their budget deliberations.

The Overview Model:

A generalized diagram of the Overview Model is shown in Figure 3. The primary inputs to this model are: (1) the *wartime* flying hour programs for each type, model, and series of aircraft, for each major conflict scenario and (2) selected spare parts data extracted from the same data base used by the Availability Model.

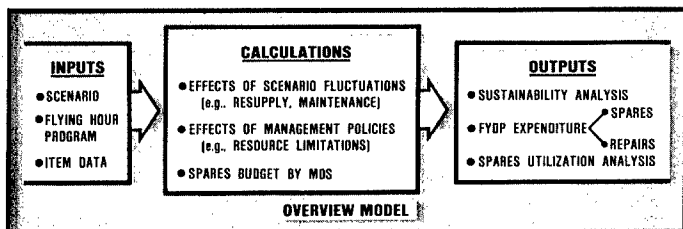


Figure 3. *Synergy Inc. (under contract to support LCMS)

The computational process for this model addresses the capability to fly at planned wartime activity levels using programmed peacetime *and* wartime stocks. The model recognizes the dynamics operating in a wartime environment; for example, variable sortie and attrition rates over time. The output options of the model include:

- (1) Sustainability analysis of each type of aircraft; i.e., how

long they can fly their wartime mission requirements (in sorties per day) and to what extent capability is degraded through the specified period of conflict.

- (2) Effect of spares and maintenance funding on the levels of sustainability.

- (3) Effect of more or less demanding flying rates.

- (4) Types of spares that are the limiting factors in meeting full wartime requirements.

- (5) Funding levels for wartime spares that are required to meet full wartime requirements. A number of input and output parameters options are available for testing assumptions (predicted attrition rates) or logistics policies (allowable cannibalization levels).

Ongoing Developments:

The LCMS methodology is now being expanded to include other important war-fighting resources such as conventional munitions and fuels. As we gain a greater understanding of how well we are providing spares support, it becomes very important to ensure that each critical resource area is programmed in a manner that guarantees balanced sustainability in wartime. LCMS will enable us to program these resources along parallel rather than divergent courses, directed toward a common measure of merit: wartime capability.

Summary

The application of these two models, comprising the LCMS, has enabled the USAF to more effectively assess the impact of program and budget decisions on aircraft readiness and sustainability. As a result, significant funding additions in fiscal years 81 and 82 were successfully supported. Combined with further programming actions for the period 1983-1987, we look forward to a continuing increase in our logistics support base in the future. Further, these tools have enabled senior Air Force managers to make better decisions on alternative funding strategies and peacetime and wartime flying hour programs. Wartime planning and capability assessment have been significantly improved, and congressional actions are now executed with a better understanding of their short- and long-term impact on national defense.

ALJ

Most Significant Article Award

The Editorial Advisory Board has selected "Precious Metals: Losses We Cannot Afford" by Lt Colonel Larry J. Goar, USAF, as the most significant article in the Fall 1982 issue of the *Air Force Journal of Logistics*.

Logistics Data Management

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Introduction

The complexity of the multinational F-16 program made it mandatory to apply Advanced Data Processing (ADP) technology to achieve effective integrated logistics support management. An Integrated Logistics Management Information System (ILMIS) has been established in IMS on-line data bases. Experience in the implementation of ILMIS, continuing enhancements, and future trends in the application of advanced data processing technology to logistics data management are addressed.

Background

The efforts addressed in this paper began during the time between the first FSD F-16 flight in late 1976 and the F-16 DSARC IIIA decision for long-lead production in early 1977. An in-depth review of program requirements and planned or available logistics management information systems revealed an urgent need for the modernization of existing systems and the development of new systems.

The F-16 program came fully endowed with the requirements for Integrated Logistics Support (ILS). These requirements were specified in a series of documents addressing the standard elements of ILS initially as manifest in DID-6138 and evolving into those as specified in AFR 800-8.

The program was subject to many innovations such as Reliability Improvement Warranty, Target Logistics Support Costs with associated demonstrations and incentive fees, the application of the Maintenance Integrated Data Access System (MIDAS) concept in the preparation of organizational-level publications, compliance with the D-220 system for spares data processing, requirements for supplying data to the System Manager's Integrated Logistics Data File (ILDF), and full application of MIL-STD-480 requiring a detailed Integrated Support Plan (ISP) in each ECP following Physical Configuration Audit (PCA).

A high level of concurrency in aircraft development and support resources development was inherent in program planning. Logistics support of the FSD program was provided by the contractor in an "arms around" mode; i.e., it was responsible and funded to provide peculiar support at all levels of maintenance. Maintenance was performed by a joint USAF/General Dynamics team employing preliminary organizational manuals in the new MIDAS format. This experience provided the foundations for the formal provisioning of support keyed to production design release in late 1977 and to initiation of F-16 operations at Hill AFB in early 1979. It was planned to have provided all organizational and intermediate support exclusive of the Avionics Intermediate Shop (AIS) with operations at Hill AFB. The AIS was planned for development completion in a two-year period spanning calendar years 1979 and 1980, during which time Avionics Interim Contractor Support (AICS) was provided.

Further, the multinational dimensions of the program were demanding. Aircraft were to be assembled at three manufacturing sites (two in Europe) supported by vendors in five countries. Activation of nine bases in six countries was required the first two years of F-16 production system operation.

It was in the context of these complex program requirements that the modernization of logistics management information systems was determined to be essential to program success. At the start, five major logistic data systems were either existing or planned for use (Figure 1). The Support Information System (SIS) was to provide a record of R&M/LSA factors, support requirements data, and task and skills data associated with each maintenance-significant item on the aircraft. SIS was to be a new system established for the F-16 program.

The Advanced Configuration Management System (ACMS) was to provide configuration status accounting on selected configuration items. ACMS was planned from the start as an advanced-technology system with disc storage and on-line access for inquiry and update.

The three remaining systems, planned for the management of spares, technical publications, and support equipment, were tape storage systems dating back to the F-111 program. These systems required the development of work sheets and card punch for computer entry, followed by computer-generated hard-copy reports and work sheets to complete the cycle. Direct access systems offered the potential for significant reduction in manpower requirements and work cycle times to more effectively achieve the anticipated work volume and rate.

The ILDF was to be an on-line data base designed, developed, and installed by the F-16 System Manager (SM) at Ogden Air Logistics Center (OO-ALC). General Dynamics data input requirements were baselined in a jointly developed *ILDF Data Dictionary* initially published in October 1976. These data were to be provided in a specified record format and integrated and sequenced by part number and federal supply codes. To meet this requirement initially, General Dynamics established an integrating data base (on disc) to properly associate support element records in a data set that would provide a record of prior submittal and accommodate periodic batch update and difference-data collection for each subsequent submittal.

Efforts were begun in 1977 to establish all systems in an IMS data base configuration with interactive on-line access for inquiry and update. Provisions were made for editing data on input to minimize error and for establishing system mechanical interfaces to accommodate common data transfer and synchronization. Key benefits to be derived were data accuracy, data currency, rapid response to change, reduction in work cycle time, and flexibility for growth and change.

Particular recognition is due the cadre of system analysts in the Data System Requirements Group under the leadership of L. W. Flomer, who have the principal responsibility for implementing the efforts described.

Patterns of Development

Although a strong sense of urgency prevailed for the immediate realization of anticipated benefits, the need to sustain a high level of performance in meeting the rapidly developing task load in each functional area was an overriding constraint in the development and installation of new methods and procedures. Initial priorities were established with due consideration of contractual milestones, availability of alternatives, task complexity, task load, and the always present constraint of resource availability. Changing program requirements and new requirements necessitated periodic adjustment in priorities.

A brief review of the development experience provides some insight into the interaction of these forces which likely characterize most major new system developments.

The *Support Information System (SIS)* and the *Advanced Configuration Management System (ACMS)* were on schedule to support the tasks for which they were planned. SIS was initially placed in production in October 1976 at the time of the first flight of the FSD aircraft. ACMS was initially installed in June 1978 in time to fully support configuration status accounting of the first production aircraft.

The *Support Equipment Management System (SEMS)* was the first system to be upgraded from a tape batch system to an on-line one. The lower magnitude and complexity of the task offered relative ease in installation and early realization of benefits.

As the program progressed, the need for two other systems, not previously addressed, was established: the *Priced Spares Parts List (PSPL)* and *Preservation and Packaging (P&P)*. The PSPL was placed in production in May 1978; the P&P system in July 1978. The early installation of these systems coincided with the threshold for rapidly increasing work load and precluded man loading increases and decreases which would have accompanied later installation.

As a result of reviewing program requirements and existing and planned data systems, it became apparent that logistics support scheduling and status activities were fragmented and incomplete. The complex interrelationships of logistics tasks in site activation and the number of countries and sites initiating operations early in the F-16 program required that a General Dynamics integrated logistics support activity be established to centralize the planning, scheduling, and control of logistics tasks to assure supportability. As an F-16 program initiative, the development of an integrated schedule status and tracking system was included in plans for modernization. Following joint USAF and General Dynamics definition of task requirements, the *Logistics Integrated Scheduling System (LISS)* was authorized in June 1978.

LISS is designed to provide an integrated record of the F-16 support system configuration and its availability in time (past, present, and future). This is accomplished in three interrelated parts: (1) a support configuration record, (2) first-article acquisition schedules, and (3) production-article order/delivery schedules (Figure 2).

The configuration record establishes the relationship of support resource requirements and the maintenance task which is represented by the reparable and the associated SMR Code. The relationships are established through a system of two-way pointers between root records.

Aircraft reparables are hierarchically related, affording spares requirements identification. At the organizational level

of maintenance, technical publications and support equipment requirements are related to the aircraft system (MIDAS/WUC) supported. At the intermediate and depot levels of maintenance, technical publications, support equipment, and software requirements are related to the individual reparable that is supported. Support equipment is similarly broken down by reparable and is interrelated to the support resources required for its operation and maintenance.

First-article acquisition schedules (for each support element record) are established for a selected array of milestones representing identification, authorization, and development. Up to six milestones, from design release to procurement recommendation through D-220, are employed for spares. Up to 25 milestones, from recommendation through final acceptance of support equipment and technical publications, are employed.

For order/delivery, an objective schedule is automatically established with reference to stored data representing procurement lead time and the date planned for initial entry of the item supported into inventory. Comparison of the objectively established order date to the first-article-acquisition completion date is made to determine if first-article acquisition will be completed in time to support the need. Actual order/delivery schedules are established to provide continuing visibility of support adequacy or the period for which support will remain deficient.

With each authorized Engineering Change Proposal (ECP), the process is repeated for every element impacted by the change. Further, the development, production, and delivery of the TCTO's/Kits are similarly scheduled and statused for each ECP.

LISS was also designed to provide continuous visibility and control of file activity. This is accomplished through a series of automatically generated action reports to identify new support elements scheduled, detect scheduling delinquencies, forecast task, and assess schedule change impacts on related support elements and supportability with initial delivery of the items supported. LISS was initially placed on production status in January 1979.

At this time, development of the new spares and technical publications on-line management systems had progressed well into the design phase. The existing tape systems had been functioning with increasing difficulty. This was particularly true in the much larger spares system. Significant efforts were being expended to modify and patch the system to meet requirements for which it was never designed. This, in itself, placed heavy demands on resources which might have otherwise been directed toward new system development. Further, it had become apparent that the spares system would not be able to sustain normal business operations by the end of the year. The system at that time consisted of 18 master files and over 290 tapes, and the time required to generate the reports essential to work processing was rapidly approaching the maximum available time in a day. A tiger team approach was adopted to accelerate development of the new spares system.

The installation of the new spares *Provisioning and Order Management System (POMS)* involved significant change in work processes, involved a larger number and variety of people, and demanded continuity in processing large volumes of data during transition. Concurrent with the technical development, an intensive, overall training program within the using organization was essential to success.

POMS was placed on production status in January 1980. Essential work flows were maintained, and fully stable operations were established within six months. Typical work flow span times were reduced from 90 days with the old system to 30 days with the new system. Through direct interaction with the computer, the provisioning analyst became more fully aware of the processes involved and the potential for improving them. As a consequence, he not only performed his job more efficiently and effectively but became a source of recommendations for improvement in the process and the man/machine interface.

With the installation of POMS, priorities were shifted to the *Technical Publications On-Line Management System (TPOLMS)*, which had progressed to a test stage. The functional partitioning of the file was such that it allowed a phased transition from the old to the new system. The scenario of user involvement and training was much like that in POMS. The old system was completely retired and full on-line operations were established in September 1980.

During the course of all the other developments, a system for the processing of maintenance (66-1) and operational (65-110) data was also under development on a low-priority basis to replace other, less-efficient means of monitoring fleet performance. The new system was named the *Systems Effectiveness Evaluation System (SEES)*. SEES consists of an on-line answer file and master tape file constructed through a specialized front-end processing technique applied to 66-1 and 65-110 data. These data are initially analyzed, combined, and sorted in a batch mode. An order-of-magnitude reduction in data storage requirements was achieved. These data are stored on a history master tape and used to update the answer file. The on-line answer file is designed to provide answers to approximately 80 questions on aircraft operations and maintenance. Answers are provided from the lowest WUC level to the fleet level by country or site within country. SEES was placed on operational status in July 1980.

Today and Tomorrow

Today, the Integrated Logistics Management Information System (ILMIS), Figure 3, consists of the nine functional modules previously identified, which in the aggregate involve:

- 18 Data Bases (IMS)
- 2474.5 Megabytes of Data Storage
- 262 CRT Terminals
- 49 Printers
- 171 On-Line Screens
- 446 Batch Reports

An average of 1.6 million on-line transactions and an average response time of less than 10 seconds are being experienced monthly.

All data bases are established with on-line access for inquiry and data entry by the user. Individual modules are mechanically interfaced by batch transfers to preclude redundant data entry, provide synchronization of common data, and initiate work processes within interfacing functional areas. Hard-copy reports are produced to meet local management needs and CDRL requirements. Magnetic tapes are produced and transmitted via mail and electronic means between the government and the contractor. Direct on-line access by the government is provided on two systems.

Engineering release system batch transfer to POMS updates the product definition daily and initiates the spares provisioning processes. Defense Logistics Supply Center (DLSC) screening for national cataloging data is accomplished overnight by two-way tape transmissions through AUTODIN. Spares recommendations are submitted to Ogden ALC via magnetic tape in the D-220 format. Purchased Item Order (PIO) tapes received from Ogden are fed back into POMS, initiating spares order release. Spares order release is accomplished through batch transfer to the systems in the Material and Manufacturing departments.

SIS upgrade has been recently completed to provide improved structure, an interface with related logistics systems, and on-line update capability. POMS is interfaced with SIS (through batch transfer) to provide synchronization of product definition, maintenance factors, source codes, and work unit codes of maintenance-significant reparables.

Ordered-part identification, quantities, and delivery data are batch transferred to the PSPL system from POMS. Data are accessed on-line to accomplish pricing task and transfer data to the spares pricing system and to generate reports for payment.

The requirement for General Dynamics-developed P&P data is established by batch update from the OO-ALC P&P tape. When requested, data codes are established by General Dynamics through on-line transaction, and P&P recommendations are integrated with subsequent ILDF submittal via magnetic tape. P&P data are reviewed and approved or changed by the SM. Approval and changes are transmitted back to General Dynamics via magnetic tape, which is fed into the P&P system for update. Packaging instruction sheets are produced via on-line print.

The ACMS is currently providing configuration status on 751 hardware and software configuration items (CI/CPCI) of the F-16 weapon system. Establishing the configuration (part number/serial number) of the CI/CPCI at time of delivery involves the accumulation and input of data from three aircraft manufacturing sites and vendor sources here and in Europe. Post-delivery accounting is accomplished through 66-1 tapes received weekly through AUTODIN.

The F-16 SPO is provided on-line inquiry access to ACMS via a telephone link. A printer, located at the SPO, affords a means for rapid communication. It is used for general message traffic and ad hoc data transfer. For example, in the event of an incident, a specific aircraft configuration can be printed out at the SPO in less than an hour following the request. The F-16 ACMS has been employed in the management of other USAF programs.

An F-16 SPO initiative to automate the status and tracking of Service Reports (SRs) from initiation to conclusion or disposition as an approved ECP is in progress. The existing ACMS currently provides status and tracking from ECP approval through ECP incorporation in production and by retrofit. In combination, these systems will provide a "single thread" of traceability from SR to final corrective action fleet-wide.

SEMS has been an effective tool in the management of support equipment (SE) and is in the process of being upgraded. In the new configuration, extensive interfacing with POMS will be accomplished, directly associating end-item SE with related spares and mechanizing end-item SE order release through POMS in the manner that spares and retrofit kits are currently released.

TPOLMS is providing a highly effective tool in the management of technical publications from proposal

development to publications delivery. Accumulating actual cost history by publication and page type is employed in the development of 40 separate negotiated factors that are applied in estimating and negotiating proposed tasks. TPOLMS is interfaced, through batch transfer, with the labor accounting system. Each week actual man-hours expended are batch-transferred from the labor accounting system and used to update TPOLMS. Each month the number of page completions of work in progress are batch-transferred from TPOLMS and used with data in the labor accounting file to develop an assessment of progress for billing.

SEES is providing rapid response to ad-hoc inquiries, whereas the history file is providing detailed assessments of maintenance history to a specific aircraft tail number and a basis for fleet trend analysis and a sorting out of effects of potential environmental, operational, and maintenance variations by country and site within country.

The LISS is established and interfaced with the POMS, SEMS, and TPOLMS systems via nightly batch transfers of common data. The F-16 SPO is provided on-line access for inquiry into LISS via telephone link. LISS has played a significant role in the increasingly complete and accurate consideration of support system impacts in the change decision and planning phase in accordance with MIL-STD-480 as well as affording timely identification and resolution of support problems.

In the course of ILMIS development, ILDF data extraction techniques, edits, formats, and elements have been revised and maintenance of a separate data set is no longer required. Today 265 data elements, provided to ILDF by General Dynamics, are combined with like data from other government sources. ILDF has an on-line processing capability which is providing rapid response to ad-hoc inquiries which span the full spectrum of engineering and logistics interest. A variety of reports are distributed to over 50 users within the government. ILDF represents an advanced concept and model for future programs in the establishment and application of an ILS data record from the initiation of the LSA process through the acquisition and modification of support resources through the life cycle of a weapon system.

Today we are beyond the initial development objectives. In addition to continually improving existing systems, other efforts are planned and in process which include the development of systems to manage inventories and repair processing, support scheduling of training, and automate the production of technical publications.

The initially documented five-year cost avoidance of over \$6 million, with an investment return in less than three years, can in no way fully reflect the intrinsic benefits associated with the system developments described. The synergistic effects of improved accuracy, currency, reduced work cycle time, and rapid response to change continue to accrue undocumented savings associated with productivity improvement. Further, the capability to plan and implement tasks within time constraints and at a level of control not previously possible is not fully subject to measurement in dollars and cents.

Assessment of computer hardware and software technology allows a focus on future development objectives leading to automatic real-time entry and electronic transfer of data laterally and vertically. Lateral transfer of data at the task accomplishment level will allow work to be initialized, sustained, and controlled. Entry and maintenance of data by other than the function responsible for task accomplishment will no longer be required. Upward transfer of data, in

summary format, will provide management visibility and control of work in progress and will support planning. Downward transfer of data will establish policy, provide direction, and authorize actions at lower levels. The summarization and analysis of historical data, current status, and forecasted tasks to provide answers to questions required for decisions, planning, and action-taking will be relegated to the computer for continuous maintenance. Manual analysis, summarization, and transfer of data will be virtually eliminated.

The potential for progress over the next five years offers the opportunity to exceed the progress of the past five years. The strong sense of urgency with which we began has never diminished.

Conclusion

The development experience has provided ample evidence that, in planning and implementing major new systems, the flexibility to adjust to unpredictable change in requirements and priorities is essential if they are to be successful and program objectives are to be met. It is reassuring that F-16 operations have been successfully established at 15 sites in 7 countries, reliability and maintainability goals have been met, logistics support cost demonstrations have resulted in full award of the incentive fee, and the mission capable rates are the best of any advanced weapon system in inventory.

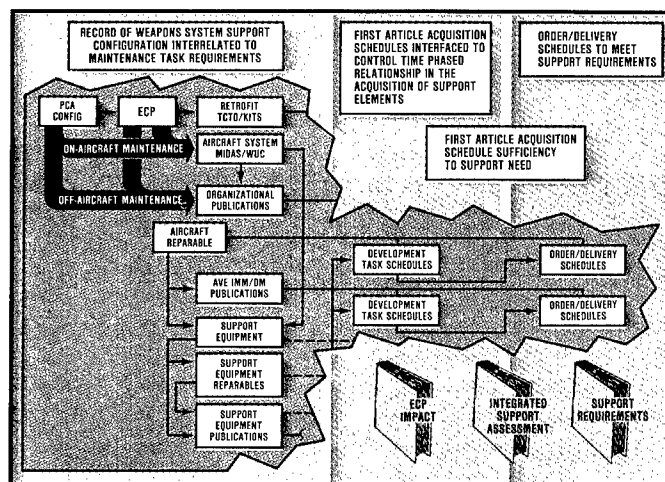
In addition to changing program requirements and priorities, the modification of work processes and organizational relationships which come with each new system and rapidly advancing computer technology have influenced the patterns of past development and will influence future development.

Initially the mechanization of new systems centers around existing organizational structures and procedures to the extent necessary to sustain essential work flows in transition. With system installation, the change in work processes and flexibility in data management (within the function served) sets in motion a process of evolution in vertical and lateral organizational interfaces. This establishes requirements for new and modified data and data systems. These requirements together with computer technology advances create a demand for continuous improvement if benefits are to be optimized.

This pattern suggests that the initial concentration of effort in the application of advanced computer technology be at the task accomplishment level. This provides for the most significant and immediate realization of benefits. Once installed, the benefits of direct interactive access to data provided by on-line capability are immediately manifest in improvements in data currency and accuracy; reduced work process span times; and, perhaps, most important, the enthusiastic grass-roots support of continued improvements.

Further, although it is true that the application of advanced computer technology offers access to virtually all program data, care is recommended in establishing requirements for data transfer upward. Upward data transfers should become more summary (though necessarily broader in scope) with successfully higher levels of management/organization. The selection of data beyond the organizational charter and staff to digest it often leads to frustration and reduced productivity through inordinate tasking downward to review and explain the data.

Institutional variations in structure and attitudes are complex. There is a practical limit to the rate at which these



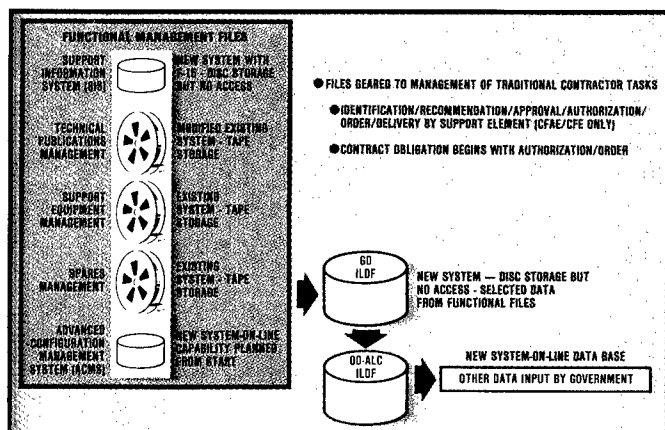


Figure 1: In the Beginning.

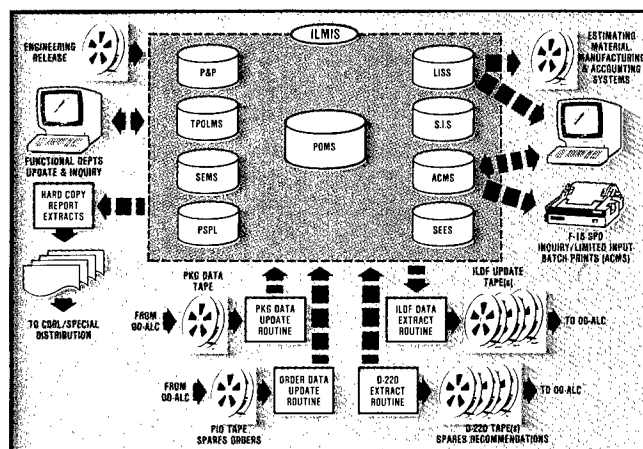


Figure 3: Integrated Logistics Management Information System (ILMIS).

Item of Interest

Transportation Productivity Improvement Guide

The Air Force Logistics Management Center (AFLMC) has published a *Transportation Productivity Improvement Guide* (TPIG) to help all mid-level Transportation managers deal with the problem of lagging productivity. Experienced transporters throughout the Air Force contributed important ideas and lessons to the Guide in the areas of General Management, Traffic Management, Vehicle Maintenance and Operations, Airlift Management, and Transportation Staff. This is an excellent tool for better transportation management in the future. The TPIG can be obtained from AFLMC/LGT, Gunter AFS, Alabama 36114.

Coming in the Spring Issue

- **Air Force Logistics Strategy**
- **Electronic Parts Obsolescence**
- **A Dyna-METRIC Trilogy**
- **Information Technology To Increase Effectiveness**



CAREER AND PERSONNEL INFORMATION

Military Career Management

Maintenance Officer Training Improvements

During the past year, career aircraft and munitions maintenance officers representing the major commands, Air Staff, Air Force Reserve, and separate operating agencies have met on four separate occasions to discuss and improve the effectiveness of our resident aircraft and munitions maintenance training programs.

The initial workshop was held at Randolph AFB, 30 Nov-4 Dec 81. It was chaired by HQ ATC and was convened as a result of a recently released Occupational Survey Report conducted by the USAF Occupational Measurement Center. The primary purpose of the workshop was to review the results of the survey of over 2,300 maintenance officers holding AFSC, or entry level AFSC, 4024, 4054A or B, 4016, or 4096 and to make appropriate changes to the basic aircraft maintenance officer course training standard (CTS). First, a very basic munitions block was developed to familiarize the student with general munitions types and procedures such as handling, safety, security, etc. Second, a "trailer block" was developed for those students having their initial assignments to the tactical air forces (TAF). The block would be included at the end of the basic course and would be designed to familiarize the students with the unique organization and maintenance concepts of the TAF. Finally, the general emphasis of the course shifted away from a detailed technical approach to a more general, systems-interrelationship/troubleshooting approach. In addition, the rated-to-maintenance and the munitions-to-aircraft maintenance courses were reviewed with similar, but less lengthy, changes being made to both.

In Feb 82, career munitions maintenance officers met at Lowry AFB. Again, three major changes were recommended to the basic munitions officer course; i.e., inclusion of a very basic aircraft maintenance orientation, addition of a TAF "trailer block," and a shift towards a systems approach.

The final two conferences were convened at Chanute AFB (Apr 82) and Lowry AFB (12-15 Oct 82) to validate the newly developed CTSs. At both meetings, the members accepted the proposed CTS and approved revised AFR 36-1, *Officer Classification*, specialty descriptions for aircraft maintenance officers, AFSC 4021/4024, and munitions maintenance officers, AFSC 4051/4054. Specific changes cannot be effected, however, until results of existing survey instruments from AFLMDC, AFHRL, and AFOMC can be reviewed and a utilization and training workshop similar to those already discussed is conducted.

In summary, career maintenance officers from the major commands and agencies are attempting to improve resident training with the ultimate goal of preparing new maintenance officers to meet the challenges of this dynamic career field. The changes discussed should be implemented within the next year.

Major Robert A. Drewitt, USAF, AFLMC, Gunter AFS AL

Civilian Career Management

Logistics Civilian Career Enhancement Program (LCCEP)

As stated in the Summer 1982 issue of the *AFJL*, one of the primary objectives of the LCCEP is to furnish the Air Force with a source of top candidates for career program position vacancies by providing developmental opportunities for them. That issue also described the need for establishing career goals and discussed the Individual Development Plan (IDP) (AF Form 2674) contained in AFR 40-110, Volume IV (25 Sep 81).

The IDP identifies your short- and long-range career goals. It also describes *where* you and management determine you should be at the end of two and later five years and what the requirements are to reach those goals. It is important to emphasize the need to work closely with your supervisor and other management officials to develop realistic goals that will benefit you and the Air Force.

After you have set your goals, the next step is to determine what training, education, and experience are needed to reach them. The IDP has space to list your requirements; and the LCCEP Career Development Panel uses that information to request funds, training quotas, and career broadening positions.

The LCCEP centrally funds long-term, full-time training programs in logistics-related fields at the Air Force Institute of Technology and at civilian universities. In addition, the LCCEP also funds programs at the Federal Executive Institute and the Executive Seminar Centers operated by the Office of Personnel Management. Because these are Air Force-wide training programs, LCCEP registrants must compete for the available spaces. As quotas are received for the various training programs, individuals are identified through the Personnel Data System-Civilian (PDS-C) from the information on the "Education/Training" block on the IDP. Candidates for short-term training are rated and ranked based on need and benefit to the Air Force. Candidates for long-term training must also have the major command's concurrence to be released for the program.

Employees needing experience in other logistics areas or functional levels should identify those desires in the "Development Assignment" block of the form. The LCCEP Career Development Panel uses this as the basis for requesting spaces for career broadening (15 at present). Individuals selected for this broadening are normally reassigned or temporarily promoted to the position for two years to gain experience in all aspects of the new job and then are moved to a predetermined position.

As you can see, the IDP is not a static document. As you reach one career goal and strive for the next, or as your training needs change, the plan should be updated to reflect your new requirements. The LCCEP will continue to use the needs identified on the IDP as a primary source for determining which developmental opportunities must be provided to best meet the Air Force mission.

Source: OCPO/MPKCL, Randolph AFB TX

Proposed Change to the Repair Cycle Demand Level Formula

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Abstract

A critical link in our national defense posture is knowing what aircraft part to send where and when to send it. Currently, two methods of determining the what, when, and where are used by base level supply managers. One is the economic order quantity (EOQ) formula used to determine stock levels of items which are not repaired when they become unserviceable. The other is the repair cycle demand level (RCDL) equation which is used to compute stock levels for items that are repaired and returned to service. Stock levels computed at the base or "retail" level are used to "pull" required assets from AFLC and other wholesale agencies. Although AFLC has developed a method (D028) to "push" some RCDL stock levels to the retail levels, most assets remain in the "pull" mode; and stock levels in the "push" equation are generated partly from RCDL data. The RCDL equation then is, and will continue to be, a vital element in determining the what, where, and when for supply organizations. For this reason, the RCDL computation should be made as accurate a tool as possible for predicting base level parts requirements.

Introduction

Current methodology used in determining repair cycle demand levels (RCDL) for Air Force repair cycle assets may not realistically address repair cycle time (RCT) for items processed through base level repair shops. Repair cycle times based on current computation methods contribute to insufficient stockage of some assets in base supply and overstockage of others. Two key factors in the current RCDL computation should be changed to reflect "real" repair cycle times. These factors are (1) the repair cycle time formula and (2) the expendability, recoverability, repairability code (ERRC) standard repair limits. The RCT formula should be revised to better reflect realistic repair time, and the ERRC repair time limits should be eliminated. This proposal outlines the current RCDL method, explains why the current method is unrealistic, and details what improvements should be made to enhance base stock levels of repair cycle assets.

Current Method

The Repair Cycle Demand Level Formula

The current method of determining the RCDL for a given asset is shown in AFM 67-1, Volume II, Part II, Chapter 11. The RCDL is based largely on the base's capability to return an asset to serviceable condition after it becomes unserviceable. Base supply must attempt to maintain adequate stocks of each repair cycle asset to compensate for the lost utility of an item undergoing repair. The repair cycle demand level formula is expressed as:

$$\text{RCDL} = \text{Repair Cycle Quantity} + \text{Order/Ship Time Quantity} + \text{NRTS/Condemned Quantity} + \text{Safety Level Quantity} + \text{Price Adjust Factor or .5 or .9 depending on unit cost}$$

The major element in the equation is the repair cycle quantity especially for those assets commonly repaired at base level.

The Repair Cycle Quantity (RCQ) Formula

The repair cycle quantity is a quantity of any given repair cycle asset which should be on hand in supply to compensate for the loss of the item during repairs accomplished at the base level. The repair cycle quantity is computed as:

$$\text{RCQ} = \text{Daily Demand Rate (DDR)} \times \text{Percent of Base Repair (PBR)} \times \text{Repair Cycle Time (RCT)}$$

Where:

$$\text{DDR} = \frac{\text{Cumulative Recurring Demands}}{(\text{Current Date} - \text{Date of First Demand})}$$

$$\text{PBR} = \frac{(\text{No. Units Repaired} \times 100)}{(\text{No. Units Repaired} + \text{No. NRTS's} + \text{No. Units Condemned})}$$

RCT is the particular aspect of this equation which is the primary area of interest. It requires a more detailed discussion.

The Repair Cycle Time (RCT) Formula

Repair cycle time is the measure of lost utility in terms of time. The RCT for a single asset is currently computed as the time between issue (ISU) date of a serviceable asset and the turn-in (TIN) date of a like serviceable asset minus awaiting parts (AWP) time (or other uncounted status time). When no serviceable asset is issued from supply, and maintenance accomplishes a turnaround (TRN) or remove, repair, and reinstall action, the RCT is simply the TRN days minus the days the asset was awaiting repair parts. These formulas are illustrated below:

$$\text{RCT} = \text{TIN date} - \text{ISU date} - \text{AWP days}$$

or:

$$\text{RCT} = \text{TRN days} - \text{AWP days}$$

The RCT for a single asset is programmatically averaged in the UNIVAC 1050-II, base supply computer, with other transactions on like assets to obtain an average RCT for all assets with the same or interchangeable stock numbers. This is accomplished as shown:

$$\text{Stock Number RCT} = \frac{\text{Total RCT}}{\text{Total repairs}}$$

This average RCT is then used along with DDR and PBR to compute the repair cycle quantity (RCQ).

The RCT Upper Limits

A hidden aspect in the computation of the RCDL is that RCT is limited programmatically in the U-1050-II computer by ERRC repair standard limits. When an item exceeds the ERRC repair standards, it automatically receives the ERRC standard RCT.

ERRC repair standard limits are as follows:

ERRC		Standard
XD1	(Depot expendable under SCARS program)	6 days
XD2	(Depot expendable under AFRAMS program)	9 days
XD3	(Depot expendable Line Replaceable Unit)	6 days
XF3	(Field expendable asset)	9 days

The ERRC standards can be overridden if the shop chief submits a request for repair exception time and receives approval.

The RCT Problems

The ERRC Limit Problem

While the base level U-1050-II uses the ERRC standards as limits in computing the "pull" RCDL, AFLC is passed the RCT unrestricted by ERRC standards for the purpose of determining wholesale stock levels. Although some asset levels are now being "pushed" to the bases, many are still and will continue to be "pulled" assets. So even if there are adequate worldwide spare assets, there is a high probability that assets with a real RCT which is above the standard will not have sufficient "pull" to meet base level needs.

The ERRC standard repair time limitation can create disparities between wholesale and retail stock levels. The ERRC standard is good in that it keeps low priority, slow-moving assets from accumulating large amounts of RCT when they are sitting in the shop awaiting maintenance behind high priority assets. But the fact remains that the ERRC standard unjustifiably limits RCT for higher and intermediate priority reparables unless the shop processes exception repair time paperwork. As you will see later on, the ERRC standard can be eliminated without adverse effects by modifying the RCT equation.

The Formula Problem

The RCT equation is a major part of the problem since it assumes that, when an asset has been issued from supply and no like asset has been turned in, the like item is either awaiting parts or being repaired. This assumption fails to address the complexities of processing repairable items through a repair shop. Shops normally have several items in the shop for repair at any given point in time. Due to manpower and machine limitations, repair priorities must be established and a backlog or queue is formed (Figure 1). High priority items are processed at the head of the queue while lower priority items are processed at the rear of the queue. High priority items are usually those assets which are in high demand and short supply. Low priority assets are usually plentiful and there is no pressing need to repair them and turn them in quickly. Consequently, those parts in short supply are usually processed first and receive low repair cycle time, which can result in lower stock levels. The slow-movers sit in the queue and build

up RCT until they reach the ERRC limit (but remember that wholesalers get the unrestricted RCT). When this happens, the imbalance continues until management takes special action to correct the situation. The example below illustrates how the current method can deteriorate stock levels:

On Julian day 360, the FMS Hydraulic Shop has two assets in the shop for repair. Item A is a hydraulic motor which is "zero balance" in supply and has caused an aircraft to be grounded. Item B is a hydraulic actuator for which a replacement has been issued the same day and is to be repaired for turn in to supply. The shop has only one hydraulic test stand and can only repair one of the items at a time. Naturally the shop repairs item A first. Item A was removed from the aircraft on day 360 and was repaired and reinstalled (TRN'd) the same day. The RCT for this transaction was:

$$RCT = TRN \text{ days } (1) - AWP \text{ days } (0) = 1 \text{ day}$$

Because of a heavy workload on the flight line, the shop chief elected to delay working on Item B. On day 364, two more parts arrived for repair and the shop chief decided to "get cracking" on that actuator. It was repaired and turned in (TIN) to supply the same day. Its RCT was:

$$RCT = TIN \text{ date } (364) - ISU \text{ date } (360) - AWP \text{ days } (0) = 4 \text{ days}$$

The part that was in plentiful supply received four days' RCT while the item in short supply received only one.

In the above example, it appears that the system operates exactly opposite to the way it should. Although this is not always the case, the situation does occur quite frequently.

A wise shop chief knows that the system can be circumvented by simply holding the part and/or its repair documentation as long as possible to build up RCT. However, the system should be designed so that there is no need to cheat.

The RCT Solution

The RCT Proposed Method

A recent Air Force move to begin using average repair times on TRN transactions is a step in the right direction. However, this move still leaves the potential for slow-moving assets to build up unrealistically high RCTs, and it does not address the problem of short-term TINs on short supply items. This latter problem could prove quite significant to organizations which have recently begun using short-term TINs in lieu of TRNs. The AFLMC proposed method for calculating RCT is designed to overcome these problems as well as to eliminate the need for ERRC standard time limits.

The proposed method smoothes out RCTs by spreading shop backlog time evenly over all the parts processed through a given shop over a given time frame. This is accomplished by first assigning each repair cycle asset and its interchangeable assets to a primary work center (PWC). Next, the PWC records actual in work (INW) time for each assigned reparable as it is repaired (shops already do this step along with other steps which will no longer be necessary). In work time for each item repaired is recorded and accumulated in supply records for each like asset. When the asset/repair documentation is turned in to supply, the computer

programmatically determines how long the item was in the shop's backlog or the "shop queue time" (SQT) by:

$$SQT = TIN \text{ date} - ISU \text{ date} - AWP \text{ days} - INW \text{ days}$$

In our previous example, SQT for the two items processed would be:

$$SQT \text{ Item A} = TRN \text{ days (1)} - AWP \text{ days (0)} - INW \text{ days (1)} = 0 \text{ days}$$

$$SQT \text{ Item B} = TIN \text{ date (364)} - ISU \text{ date (360)} - AWP \text{ days (0)} - INW \text{ days (1)} = 3 \text{ days}$$

Now to spread the SQT evenly over all the assets processed, an average SQT (ASQT) is calculated for the *work center*. This is found by:

$$ASQT = \frac{(SQTa + SQTb + SQTc + \dots)}{\text{Total Items Repaired}}$$

Again in our example, ASQT would be:

$$ASQT = \frac{(SQTa (0) + SQTb (3))}{\text{Total Items Repaired (2)}}$$

$$= 1.5 \text{ which could be rounded up to 2 days}$$

ASQT is cumulative over time and is recalculated as each transaction is processed, providing continuous updates to the RCDL calculation. Now RCT can be calculated for each individual stock number by simply summing the INW days, dividing by the total number of repairs for the stock number, and adding the ASQT to the result. Returning to our example, RCT would be computed as follows:

$$RCT \text{ Item A} = \frac{INW \text{ days (1)}}{\text{Total Transactions (1)}} + ASQT (2) = 3 \text{ days RCT}$$

$$RCT \text{ Item B} = \frac{INW \text{ days (1)}}{\text{Total Transactions (1)}} + ASQT (2) = 3 \text{ days RCT}$$

Now remember that AWP time has already been deducted from the individual transactions in the SQT calculation. Calculation of RCT in this manner represents a more equitable distribution of lost time utility for repair. Item A's RCT was increased by two days while Item B's RCT was reduced by one day (See Figures 1 and 2 for comparison).

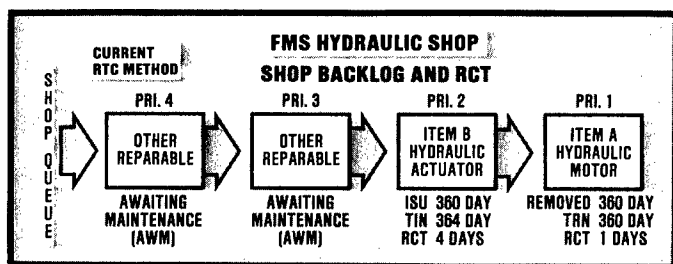


Figure 1.

ERRC Limits Not Required

This RCT reduction on slow-moving items eliminates the need for the ERRC standards since they now cannot

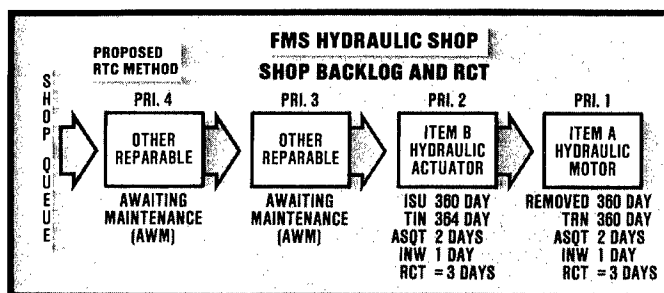


Figure 2.

accumulate long periods of queue time in their RCT while awaiting maintenance. Removing the ERRC standards also allows the short supply items to "catch up" on RCT without added paperwork in the event they are actually in work for long periods of time. Long in work times are becoming the rule rather than the exception for some late model avionics items.

Additional Benefits

As an added benefit, work center ASQT provides maintenance and supply managers with a highly visible performance indicator for repair shops. Abnormal fluctuations in ASQT for a given shop would show that something had changed to raise or lower the shop's average backlog and that management attention may be required to correct deficiencies or praise efficiencies. However, it should be noted that static comparison between ASQTs of different shops would be virtually useless, and even destructive in some cases. Another benefit of the proposed calculation is that wholesale levels would also receive more accurate RCT based on actual in work time plus average shop queue time. This would enhance the distribution of worldwide assets regardless of whether the asset is under the "push" or "pull" system.

Conclusions

The AFLMC verified the value of this proposal to the extent feasible by performing computer analysis of the RCDL formula under both the current method and the proposed method. In exercising the formula, actual supply data was used to determine the sensitivity of the RCDL formula to the proposed changes in RCT computations. It was shown that stock levels for many high-flow assets were increased by one or two units, while slower moving assets were less affected. In fact, the slowest moving parts with stock levels of one unit were not affected at all, showing that the desired effect is produced by the proposed method.

The proposed method will require additional computer space and processing time in the supply computer, and may not be implementable until Phase IV computers are on line. But considering the potential benefits offered by the new method, and the criticality of properly managing repair cycle assets, it should be placed high on the priority list for future improvements in base supply automation. It will undoubtedly provide better answers to the what, where, and when question and strengthen a vital link in our capability to "Fly and Fight."

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The New Frontier—Warranted Tools

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Background

Having the right tools, parts, technical information, and trained people in the right place at the right time is fundamental to effective logistics support. This article addresses a small, but essential, part of the logistics support equation—the need to have the right tools to perform aircraft maintenance. The right tools in this case are those of sufficient strength and endurance. To aid in reaching that end, the Air Force Logistics Management Center (AFLMC) has just completed an in-depth study on the apparent problem of low-quality hand tools used by Air Force aircraft maintenance personnel.

This problem was first brought to the attention of the AFLMC through a letter from the Director of Aircraft Maintenance, Strategic Air Command (SAC), in 1978. The letter stated in part:

The quality of hand tools being procured for Air Force use has caused considerable concern throughout our command—especially at the level of the tool user where specific tech order torque/stress requirements exist for the application and removal of component parts, instruments, etc. Too frequently there is a great deal of breakage or tool failure indicating either the tool did not meet the required tool specifications, or the tool specifications did not meet the job requirements. In the past, we have bought quantity at the cheapest cost. Now, with improved tool control, reduced tool authorizations, and increased utilization of each tool possessed as a result of the Consolidated Tool Kit Program, we urge a comprehensive evaluation of the cost impact of purchasing quality tools versus the economy of purchasing low bid contract tools.

The Study

In response to SAC's request, the AFLMC initiated a new project. The study would focus on hand tool procurement procedures, the Air Force Composite Tool Kit (CTK) program, the materiel deficiency reporting system, and verification of actual hand tool failures Air Force wide. This article reports the results of that study.

Hand Tool Procurement

The General Services Administration (GSA) Tools Commodity Center is the central procurement agency for all DOD hand tools. Yearly contracts are let through invitations for bid. The GSA solicitation includes specifications for each tool item. When using government specifications, GSA can encounter difficulty in obtaining bids for particular hand tools. This problem arises because many suppliers cannot satisfy

these requirements with their usual off-the-shelf items. Because government contracts account for only 2% of the total commercial tool vendor's trade, few companies are motivated to retool to meet government specifications. Partially because of this problem, GSA has been steadily moving away from federal specifications for hand tools. Currently, the move is toward *commercial item descriptions* (CIDs) or typical *commercial specifications* for off-the-shelf tool items. However, when GSA uses commercial item descriptions and then buys from the lowest responsive, responsible bidder, the resultant item often is not a tool which will adequately meet the needs of the Air Force.

For example, in jet engine disassembly, the *breakaway torque* on some fasteners can be more than three times the *application torque*. This is caused by the constant and regular heating and cooling of the engine, corrosion, and other factors. In this situation the Air Force must have high-strength sockets, ratchets, and other tools which can withstand repeated high torque applications without breaking. To reiterate, because of the procurement techniques forced upon GSA by law, low priced tools may not, in many cases, be meeting the needs of the Air Force.

Hand Tool Deficiency Investigation

Verifying the hand tool breakage problem and identifying the actual causes of breakdown were therefore the first steps in the tool study.

Composite Tool Kits

In 1971, most major commands in the Air Force began converting from individual tool boxes to the Composite Tool Kit (CTK) Program. The CTK system is based on four concepts:

- (1) Tools for several technicians are consolidated into a single tool kit.
- (2) Tools are arranged in an orderly manner with a specific location for each tool, either on a shadow board or in a box, with inlays of plastic or foam.
- (3) Tools are inventoried frequently to maintain accountability, which reduces the incidence of foreign object damage (FOD).
- (4) Functional area managers assume a larger share of the responsibility of tool control.

The use of CTKs in Air Force aircraft maintenance resulted in increased tool accountability which reduced the incidence of foreign object damage and lost tools. CTKs also reduced tool inventories and generally increased productivity. However, since the CTK concept forces a relatively small number of tools to be used by a relatively large group of mechanics, we determined that the CTK system had in fact contributed to

increased tool failures, evident in greater breakage and wear-outs.

AFLMC Survey

In April 1978, the AFLMC surveyed seven Air Force major commands, the Air National Guard, and the Air Force Reserve to determine if hand tool deficiencies were a common problem. Some concerns of maintenance personnel included: high levels of tool failures due to poor tool quality, lack of tool size standardization which sometimes forces reconfiguration of the CTKs, personnel injury (mostly knuckle-busters), damage to equipment, time lost on the job to replace broken tools, costs of replacement, and overall worker frustration. Even though the vast majority of responses did verify a serious tool problem, it is important to note that 20% of the respondents did feel the GSA supplied tools were adequately meeting their needs and hand tool failures did not pose a significant problem. The majority of those respondents were performing maintenance (avionics), which did not have high-torque requirements.

Quality Deficiency Reporting System

The Quality Deficiency Reporting (QDR) system is used by the Air Force and DOD to report deficient hand tools to GSA. After investigating this system, the AFLMC found that the information required by GSA for corrective action to deal with a tool deficiency (for example, the contract number, purchase order, or document number) was not available to the mechanic completing the QDR form. This then resulted in a majority of the QDRs being administratively closed (80% for an 18-month period ending in Nov 78) without being submitted to GSA for formal investigation. GSA was probably not aware, through no fault of their own, of the magnitude of the iceberg and in this case they were only seeing the tip of the problem.

Identifying High Failure Tool Items

For the next step, the AFLMC in 1979 collected actual hand tool failure data from 25 jet engine maintenance shops in five major commands to identify high failure tool items. The jet engine shop was chosen because the work load and critical applications placed on hand tools used in this location would provide good reliability data. The sample consisted of various sized jet engine maintenance shops representing a wide range of engine types. After eight months of data collection, 5,010 tools had failed, which was about 13% of the total tool authorization in those shops. After further analysis of the data, 54 of the 366 failed items represented 42% of all tool failures. These items included, among others, universal sockets, regular and deep sockets (both 1/4" and 3/8" drive), ratchets, speeder handles, extensions, open and box wrenches, needle nose pliers, and cotter key extractors. These 54 items were then selected as the primary warranty tool candidates.

Why Warranted Tools?

Long-term tool warranties have been used in commercial aircraft maintenance shops for some time. In industry terms, a long-term warranted tool implies high strength and high quality. The rationale is that under the warranted tool concept

all tools which fail to provide satisfactory service are replaced free of charge by the vendor. This places sole responsibility for tool quality on the contractor. The vendor is much more aware of failure patterns of warranted tools and is obviously more responsive and knowledgeable in developing appropriate modifications to improve reliability. Purely economic reasons will force the contractor to respond to tool deficiencies rapidly and in turn urge him to introduce production and design changes that will increase any tool's mean-time-between-failure. Also, it is implied within the concept that the contractor is reputable and will "stand behind" the product sold. After several inquiries, AFLMC discovered there were tool vendors who would provide their "top of the line" quality tools to the Air Force under warranty conditions and who could be depended upon.

Economic Analysis

The main disadvantage of purchasing long-term warranted tools is the relatively high initial investment cost. To determine the economic feasibility of purchasing warranted tools, the AFLMC, using the tool failure data collected from the 25 jet engine shops, computed the number of years required to pay back the initial cost of warranted tools. The payback analysis was performed with consideration given to both constant dollars (without inflation) and current dollars (with inflation). DODI 7041.3, Enclosure 2, Paragraph B.4.d., requires the economic analysis to be performed using this method.

The formula for constant dollars is:

$$cz = cx + gxv(i)$$

where c = number of tools authorized
 z = cost of warranted tool item
 x = cost of GSA similar tool item
 g = failures per year (af)
 a = shops reporting that item
 f = broken per shop per year (12e)
 e = broken per shop per month $\frac{d}{b}$
 d = tools broken
 b = total months tool data was reported
 $v(i)$ = the accumulated value of the discount factors through year (i).

However, if an allowance is made for inflation, the formula is expressed in current dollars. If, for example, the discount factor is cancelled out, the formula for current dollars becomes:

$$cz = cx + gxy$$
$$y = \text{payback in years} = \frac{c(z - x)}{gx}$$

Using this methodology, a comparison was made between 186 SNAP-ON (a commercial brand name) tools and similar GSA tools to determine the length of time required to pay back the higher purchase of SNAP-ON tools. SNAP-ON tool prices were used for comparative analysis because their prices were among the highest in the industry and would provide the "worst case" for payback analysis purposes.

The economic feasibility comparison using the formula for current dollars showed that out of 186 tool items, 35 tools had a payback of five years or less. The payback for all 186 tools was 13.1 years.

It was assumed in the analysis that warranted tools which fail to give satisfactory service would be replaced free of charge by the vendor. Also, no allowance was made for lost tools. Furthermore, the assumed failure rate for tools which could be economically considered as warranted tool candidates is approximately 15% per year. However, for higher priced warranted tools, the failure rate would certainly be higher.

Conclusions of the Study

The problem of hand tool breakage is very complex because of many contributing factors. The changeover from individual tool kits to composite ones contributed to the high failure rates for some items. Also, the study concluded that due to the ineffective quality deficiency reporting system, the federal specifications for hand tools have not been revised to ensure high-quality tools. Consistently, the most common concerns of tool users included poor tool quality, lack of tool standardization, high incidence of foreign object damage, personnel injury, equipment damage, high replacement costs, time lost on the job, and overall frustration of the tool user.

Where and when selectively applied, our payback analysis showed that the replacement cost for tools over the long run could be reduced significantly by purchasing high-quality warranted tools. The Air Force spends approximately \$8.2 million per year for replacement tools. The AFLMC study estimated the Air Force could in fact save approximately \$2 million per year after payback by purchasing selected groups of warranted tools.

Perhaps even more important, other possible benefits to be derived were:

- (1) Higher morale of the maintenance technicians.
- (2) Reduced accidents and personnel injuries.
- (3) Reduced tool inventories. (Of the 366 NSN's reported as deficient in the study, 59 NSN's could be eliminated without affecting mission capability of the survey bases.)
- (4) Reduced incidence of foreign object damage.
- (5) Reduced frustration on the part of the tool user.
- (6) Reduced incidence of equipment damage.
- (7) Increased maintenance productivity.

Recommendations

After completing the hand tool study in 1980, the AFLMC recommended selected GSA hand tools used in Air Force maintenance activities be replaced with long-term warranted items.

In 1980, the Air Force found GSA to be very receptive to implementing the warranted hand tool program. After several meetings between GSA, HQ USAF/LEY, and AFLMC, it was decided the warranted tools would be purchased by GSA using a 12-month indefinite quantity contract. However, because of the experimental nature of the program, two constraints were placed on this phase of the program. First, the number of warranted tools was limited to less than 100. And, secondly, because this phase of the program was considered a test of the new concept, the scope of the program was limited to the use of the warranted tools in one Air Force shop in the United

States. The shop chosen to receive the first of the warranted tools was the jet engine shop. Approximately 155 Air Force, NGB, and AFRES bases in the United States were eligible to participate in the program.

The Solicitation for Warranted Tools

The philosophy inherent in the approach to the solicitation was to make sure the tool industry got a straightforward request for common hand tools without using federal specifications, metallurgical testing, or item samples. This concept conforms to the program of buying commercial off-the-shelf items without increasing overhead costs due to federal regulations. The negotiated solicitation was structured by GSA to foster competition between vendors. An incentive was built into the solicitation to reward the vendors who offered longer warranty periods. A longer warranty implies higher quality, but also increases the economic risk to the vendor. Also, complete sets, or aggregate groups, of warranted tool items were listed in the solicitation. These sets were constructed by the AFLMC from the listing of high failure items in the tool study. Additionally, the Air Force furnished GSA with a guarantee to purchase a minimum quantity of each tool item. In March 1981, the prospective vendors were briefed by the Air Force and GSA concerning the impending solicitation. Also, a vendor's solicitation conference was held by GSA in August 1981 to explain the requirements of the solicitation.

Contract Awards

Five vendors submitted offers for the first warranted tool contract. After subsequent negotiation by GSA, two contracts were awarded by them. The first, for 83 items, went to SNAP-ON Tool Corporation in February 1982. That company offered an indefinite warranty with on-base servicing for exchange of broken tools. SNAP-ON's warranty states: "... SNAP-ON will replace or repair, after inspection, at its cost, all SNAP-ON hand tools or parts thereof which fail to give satisfactory service. . . ." The second contract was awarded to the Fraunholtz Tool Company in April 1982. That company, a small business distributor of name brand tools, was awarded 12 items. Fraunholtz would supply the Air Force with Diamond Tool Company needle nose pliers and diagonal cutting pliers, plus ten different Stanley Tool Company screwdrivers. Fraunholtz guaranteed these tools for 15 years with replacement of failed items to be made by mail exchange.

Warranted Tool Program Implementation

HQ USAF/LEY (Director of Maintenance and Supply) approved the warranted tool plan which was written by the AFLMC and distributed in March 1982. The plan was broken down into procedures for maintenance, supply, and contracting. It outlined the procedures used for requisitioning new tools and replacing broken tools. The exchange of broken tools is centralized at each base tool issue center. This is done so that the vendor has only one point of contact to deal with for exchanging broken tools at each base. Primary consideration was given to making the procedures as streamlined as possible to interface with the Air Force standard base-level supply system.

Evaluation of the Program

Currently, the program is in the evaluation stage. Warranted tools have replaced GSA similar items in jet engine shops. Also, data is being collected from 16 evaluation bases (15 of the original 25 evaluation bases plus the Oklahoma City Air Logistics Center propulsion division).

The methodology which will be used to evaluate the program's effectiveness is divided into three parts. First, a direct comparison of the past GSA failure rates with warranted tool failures will be made using data collected from the 15 evaluation bases. Significantly reduced failure rates will be an indication of program success. Secondly, using actual prices for the warranted tools, the AFLMC will use a modified break-even analysis test and project the life cycle cost savings over the life of the warranted tools. Lastly, a survey will be administered to warranted tool users to obtain their perceptions as to the success of the program. After the use data has been gathered and analyzed, a final report will be written by May 83

and, if justified, the warranted tool program will be expanded. Expansion will include additional tool items and other maintenance shops and, again, will depend on the results of program evaluation.

Conclusion

The ever-increasing problem of inferior and deficient hand tools throughout the Air Force maintenance community has been investigated and verified by the AFLMC. In response to the AFLMC findings, the GSA Tools Commodity Center is taking a new and innovative approach to correct these deficiencies. With the selective replacement of high-failure rate, non-warranted tools with long-term warranted tools, not only could the program provide a substantial monetary savings to the Air Force, but it could also make sure the "right" tools are in the hands of the maintenance technicians. This translates into increased morale and more maintenance production. **AES**

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Primary incentives include contractor investment protection to allow amortization of plant and equipment, and productivity shared savings rewards which result from productivity enhancing capital investments.

Containerized Ammunition Expanded

The Air Force is leading the way toward increased use of containers to move munitions to the Pacific. As breakbulk ships leave commercial service, their availability in wartime poses serious difficulties. In August 1981, the Air Force conducted its first series of planned tests known as CADS I (Containerized Ammunition Distribution System). Eighty-six MILVANs were moved from CONUS storage sites to Korean munitions storage areas. This was followed by CADS II in May 1982. Fifty MILVANs were moved from Okinawa, Japan, to Korea. Both movements were most successful, providing know-how in port handling and transfer capabilities. These tests have formed the basis for routine containerized movement of munitions to overseas areas in the future.

Air Transportable Fuels System Improved

For years the Air Force has maintained a substantial Air Transportable Fuels System (ATFS) package, potentially capable of providing the entire spectrum of fuels support in bare/austere base environments. Modernization from Vietnam era equipment to the state-of-the-art has just begun to occur, driven by the demand of today's requirements for rapid response and increased flexibility in wartime scenarios. Planned improvements include remanufacture and new production of critical fuel dispensing modules; replacement of aging equipment items; and standardization to multifuel engines. In a corollary program, a bare base capability for cryogenics support, ranging from product generation to line haul transport, is being pursued. The net result will be a petroleum and cryogenics support capability in consonance with the momentum of today's logistics planning.

Word Processing Planned for Personal Property Shipping Offices

Word processing systems will be tested at five Air Force personal property shipping offices this winter. Test objectives are to demonstrate word processing capability to substantially reduce the manual workload associated with preparation, control, and distribution of documents and maintenance of registers, records, and files. Test results will determine if word processing systems should be expanded Air Force wide as an interim measure until the Transportation Operational Personal Property Standard System (TOPS) can be fully developed and implemented or if word processing is a practical and cost-effective alternative to TOPS.



Leadership and Management - Why the Confusion?

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Introduction

An erudite and well-diagrammed article in the Spring issue of the *Air Force Journal of Logistics* by Major Robert G. Sims, USAF, sought to clarify in simple terms the difference between leadership and management. From his diagrammatic approach, Major Sims came up with still another definition for each of the terms. But has he not, perhaps, added to the already considerable confusion that exists among those who write or teach these two subjects?

Background

I would like to draw on some 45 years of military or military-associated experience to add a few comments to this perennial discussion and, perhaps, persuade a few readers that leadership and management *can* be clearly separated—separated both in understanding and application—and that it is essential that not only are the differences understood but that the correct philosophy be applied.

In my first 15 years in the military we rarely, if ever, talked of management. The emphasis in every military school and directive was on leadership. Admittedly, there were five grim war years in that period when, undoubtedly, leadership was the very key to success in battle. It was epitomized by Winston Churchill in those years. But with World War II over, the emphasis needed to be changed and, while continuing to have a need for leadership, the pressing requirement should have been for improved management. The British electorate observed this at the first postwar election when they discarded their wartime *leader* for one they considered a more suitable Prime Minister, one who would resolve postwar problems and *manage* the transition of a country from war to peace.

However, in the British Military the term “management” had no place. The wartime top managers recruited from the business world—such people as Lord Beaverbrook and Lord Nuffield—had long departed to return to their lucrative business fields. The war had discovered, developed, and promoted the military leaders, the victors of battle. These leaders were now directing the Services, and their battle-ground leadership philosophy continued in a peacetime environment. The problems in the military, however, were analogous to those in the country; and the increasing need was to *manage* the transition from war to peace. If this transition were described as organized chaos, it would be flattering. Then along came the so-called Cold War and, again, came the

increasing need for the management of resources. But management was a philosophy that was not practiced. I recall the mismanagement that was so evident and prevalent when conscription was introduced in Great Britain at that time. Leaders we had; managers were few and far between.

In the early fifties, I was fortunate enough to be selected to attend the USAF Air War College; subsequently, I was assigned to the (then) Air Materiel Command—today’s AF Logistics Command. In those three years I saw the USAF transition from the “press-on-regardless” era to the era of management. I saw the recognition that “resources” (identified by Maj Sims as “people, money, equipment, time, space, information, and energy”) were no longer unlimited, nor always available. Resources had to be managed. At that time, management, to me, was as much a new word in my lexicon as “logistics.” In those three years, however, I quickly learned the meaning of both terms. I also learned the difference between leadership and management although, at that time, I could not have given you a definition of either.

On my return to England at the end of that tour, having learned from my experience with the USAF, I explored the application of management techniques in the RAF. I found that what was a tidal wave in the American Military was just a ripple in the British Services. The emphasis was still on leadership. However, my assignment was such that I was able to prepare and present a number of papers illustrating USAF logistics management techniques and suggest their applicability to the Royal Air Force. This, coupled with increasing emphasis on doing more with less, and the steady flow of information on computer management information systems that came across the Atlantic in the late fifties, convinced the British Military that long-neglected management techniques must receive increasing emphasis.

In 1959 I again found myself back in the United States, this time as a member of the faculty of the School of Systems and Logistics, teaching management-logistics management and continuing to take more than an historian’s interest in the vacillating fortunes of the American Forces. In the last 20 years I have observed the trend which started in the fifties to continue to de-emphasize the philosophy of leadership and place instead increasing emphasis on management. The need for this accentuation cannot be disputed. Resources, as defined by Major Sims, have become increasingly more valuable; more limited; and, consequently, more expensive. However, leadership is no less a requirement in today’s environment than it was in other eras. Leadership and management together do not make a finite whole. If the emphasis is increased in one, it does not follow that it must decrease in the other. Until the differences between the two are understood, however, there will continue to be an imbalance in the application of the two philosophies. Frequently, it has appeared that those who should be leading were, in fact, managing; and, just as frequently, those responsible for managing were leading. My armchair observations indicate that this confusion has been prevalent at all levels of

command. *The confusion is causing drift, deviation, indecision, and ill-defined direction.* I do see the pendulum beginning to swing once more toward the leadership role and a better awareness of the difference between what is meant by leadership and management. Directions are becoming clearer, simpler, and more understandable; there is more of "this is what needs to be done" and less of "this is how it is to be done." It is essential that the fine balance between the exercise of leadership and the application of management be attained. To reach that balance, there must be a recognition and understanding of the meaning of both and the necessity to practice both so that they complement each other.

A short while ago I came across an article in the RAF magazine, *Supply*, on this very subject. The writer (Flight Lieutenant R.D. Bushby, R.A.F.), a Supply Officer, wrote "...we have become so besotted with management and all its associated paraphernalia such as: cost-effectiveness, statistics, ADP and a multitude of quasi-mathematical practices. Certainly, management has its place, but a good leader who is a bad manager is of more use to our Service than the reverse. When our backs are against the wall, either literally or in a ministry meeting, it is leadership that counts in rallying the troops - not management." This young officer has a good grasp of the essential requirements to run a system or an organization or a military service. We must recognize the differences in the terms as well as their relationship to each other.

I suggest then that all of us who have any responsibility for an efficient smooth-running logistics system or elements of such a system would do well to take to heart the dictum of Field Marshal Lord Slim who, addressing the Australian Staff College on this subject several years ago, described leadership as "...being of the spirit compounded of personality and vision - its practice is an art. Management is of the mind, compounded of statistics, methods, time-tables, calculations - its practice is a science." Lord Slim further went on to say, "Managers are necessary - Leaders are essential."

Many of today's problems can be attributed to the failure to make this distinction.

Linear Responsibility Charting: A Tool for Clarifying Roles and Responsibilities in Your Organization

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Abstract

How often do conflicts arise in your functional area over specific roles and responsibilities? How often are you or your subordinates confused over the relationships between various entities in your organization? Many managers waste valuable time in determining the answers to these questions. In this article, I will explain why linear responsibility charting (LRC) is an excellent tool for clarifying the roles and responsibilities that exist within an organization and also compare it to the traditional organizational chart.

The Traditional Approach: The Organizational Chart

The most common method of diagramming an organization is with the traditional organizational chart. A portion of a hypothetical organizational chart is shown in Figure 1. From this chart it is possible to make two determinations. First, the chart shows the lines of formal authority. The commanders and supervisors are clearly identified. The commander has authority over the deputy commanders and so forth down the chart. Secondly, the chart shows the units that exist within the organization. The various units, such as the command post, aircraft maintenance, passenger service, etc., are clearly identified.

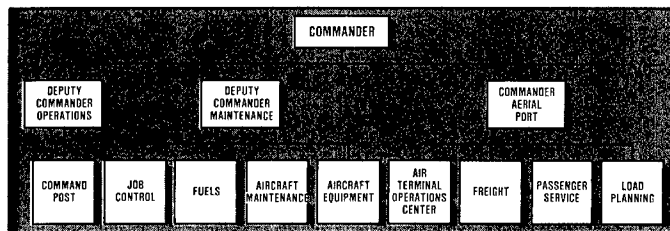


Figure 1.

Unfortunately, many items are left out of the organizational chart. D. A. Heming¹ identified several areas, or flaws, that exist in the organizational chart as a tool for describing roles and responsibilities within the organization. These can be:

(1) Status. The organizational chart does not show where decision power actually lies. In our chart, for example, the command post may have a great deal of authority over activities on the chart, although the traditional organizational chart does not show this.

(2) Degree of responsibility and/or authority. There are many instances where units, sections, squadrons, etc., are shown on the same level but in reality have specific responsibilities, authority, or power over other equally charted entities. In the chart presented, job control under the deputy commander for maintenance may well have power over the other units depicted, since this unit may direct the activities of the other units.

(3) Line/staff relationships. The traditional organizational chart shows no interaction between line and staff functions. If our example chart in Figure 1 were expanded to show the personnel section, there would be no means of depicting its relationship with the other units on the chart. Clearly, other staff functions (accounting and finance) would have close relationships with the line functions (maintenance, transportation, etc.).

(4) Lines of communication. Who talks to whom? How is coordination accomplished? It is not possible to show these cross lines of communication on the organizational chart. In our example chart, one would expect much communication between the command post and many of the other units; however, this cannot be shown on the chart.

(5) Informal organization. The intergroup and interpersonal relationships within the organization are not indicated, nor is there a means to show these relationships. Often the formal organization, as charted, proves ineffective in meeting specified goals or objectives. When this occurs, the informal organization arises. The formal structure is modified in the interest of task accomplishment; but perhaps due to

organizational policies, this informal structure is not acknowledged on the organizational chart.

(6) Organizational relationships. Working relationships between commanders, supervisors, and other personnel within the organization cannot be shown. The extent of necessary cooperation between units is not indicated.

We can see that the traditional organizational chart has many shortcomings as a tool for understanding the organization. D.A. Heming² summarized these shortcomings by stating that:

... it [the traditional organizational chart] does not give a comprehensive picture of the organization and its workings. It is merely a device or map that shows in graphic form the organization's operational units, and formal lines of authority. The average chart presents the vertical relationships between supervisor and subordinate, between the various organizational units, and formal lines of authority. Because it tends to show what the structure is supposed to be, rather than what it really is, the organization chart tends to become meaningless.

What is linear responsibility charting?

Simply defined, linear responsibility charting is a graphic presentation of the organization as it actually functions. LRC was developed in the 1950s at Corning Glass Company as a means to clarify responsibilities by putting them on one sheet of paper and displaying them.

LRC provides the means to overcome many of the shortcomings of the organizational chart. In addition, LRC aids in other areas. It prevents overlapping of responsibility and authority by clearly identifying roles and responsibilities for various entities within the organization and prevents duplication of efforts in task accomplishment. Through elimination of much confusion within the organization, and as a diagnostic tool, LRC can prevent work overload, as well as underload, within the various units. This, in turn, reduces frustration and improves the organizational morale.

What are the mechanics of linear responsibility charting?

The mechanics of LRC have been most aptly presented by Dr. John LeBlanc of the University of Southern California.³ I have personally used his approach. The key to LRC is the use of symbols to identify roles and responsibilities within the organization. These symbols identify supervisors, those who actually do the work, decision makers, coordinators, and others for the particular organization.

I have presented, in Figure 2, a linear responsibility chart for the traditional organizational chart presented in Figure 1. The chart is quite different from a traditional one. Horizontally across the top of the chart, there is a list of specific entities which make up the scope of concern within the organization. These entities can be specific people or units and are generally those that exist on the organizational chart.

Along the vertical column, there is a list of activities or events that require some type of action or awareness by the organizational entities. This is an added dimension, along with symbols, that makes LRC such a useful tool. In this example, I have selected aircraft activities; but other activities associated with personnel, accounting, finance, supply, and public relations can be added.

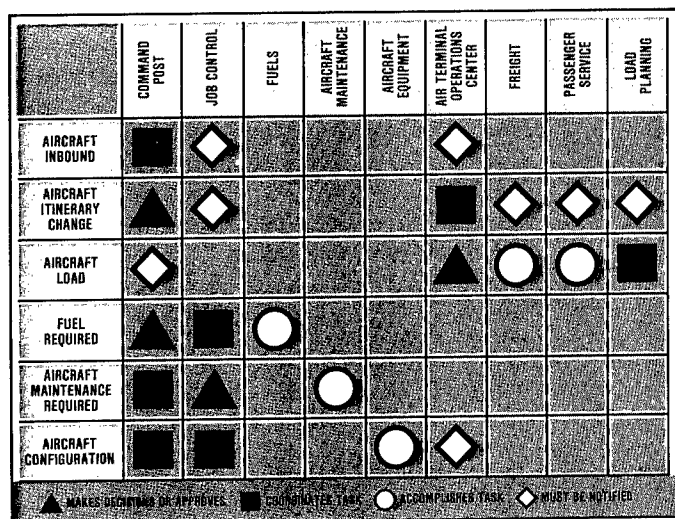


Figure 2.

Now we come to the key to LRC—symbolology. Symbols are selected which indicate appropriate relationships and the necessary amount of involvement and responsibility. In the example, I have chosen four symbols that reflect decision making, coordinating, and actual task accomplishment, and those that require notification. LeBlanc lists others that may be appropriate for use within your organization:

- Plans and controls the activity. May be particularly useful to identify administrative activities.
- △ Makes technical decision. Technical or delegated decisions made at lower levels; a specific maintenance action to correct a problem.
- ◊ Acts as consultant. This may be useful for showing where assistance may be rendered within the organization to facilitate accomplishment of a specific task.
- ⊗ Recommends. May be useful for showing a required step in the decision making process.
- ⊠ Reviews and counsels. Some activities may require review or counseling prior to task accomplishment or further activity.

Other symbols can be added as necessary to represent the process of your organization. The selection of symbols used in this article is not mandatory; if they appear too confusing or unnecessarily complicated, numbers or letters can be easily used in their place. The important point is to use what will work best and would be the most appropriate within your organization.

Looking at the activity of aircraft loading, we can see several events that take place within the organization (Figure 2). The air terminal operations center decides on the applicable load for the aircraft; the load planning unit coordinates the task; freight and passenger service do the actual loading; and finally the command post must be notified of the actual load. Similarly, by examining the other activities, roles and responsibilities within the organization become evident.

Notice on the chart that the command post is involved in all of the activities listed. Contrast this with the traditional organizational chart in Figure 1 which shows the command post in a vacuum, isolated from the other units on the chart. This contrast should make the usefulness of linear responsibility charting clearly evident.

Benefits of Linear Responsibility Charting

LRC can tell you at a glance what is actually happening within your organization and what types of relationships exist. Additionally, the organizational management can see how well the structure is working toward task and goal accomplishment.

LeBlanc also indicates that LRC can be used as a diagnostic tool. He points out seven diagnostic functions of LRC:

- (1) Pinpoint who does what.
- (2) Clarify degrees of responsibility.
- (3) Spot organizational errors quickly.
- (4) Eliminate unnecessary job duplication.
- (5) Set visual management controls.
- (6) Communicate task realignment.
- (7) Speed up management audits.

One final benefit of LRC is that of optimization of human resources. The total process of LRC should make the Air Force manager more aware of personnel manning requirements. The advantage of this should be clearly evident in coping with personnel shortages that exist and are predicted within the Air Force.

Limitations of Linear Responsibility Charting

LRC is not an answer to all problems nor is it intended as a replacement for the traditional organizational charts. These charts are still best for showing unit divisions and supervisory structure within the organization. However, LRC should be used in conjunction with the traditional organizational chart for maximum understanding and comprehension of its structure and operation.

The symbols used cannot show all relationships and degrees of relationships within the specific area of each symbol. Coordination, for example, could require only a simple yes or no, or may require hours of discussion, research, and deliberation.

A well-constructed linear responsibility chart will take time to accomplish properly. Charting the varied relationships within complex organizations is a difficult task, but one that should be worth the effort.

Use with Military Plans

LRC would be an extremely useful tool in conjunction with military plans. Most of these plans are not practiced often; therefore, personnel are not readily familiar with their roles and responsibilities. Think of originating a plan and having an LRC at your fingertips so that it is clearly evident, at a glance, what the roles and responsibilities are for implementation and operation! In fact, many plans have failed, or at least been only partially effective, because someone or some unit was unaware of their role or responsibility.

Conclusion

LRC represents a vast improvement over the organizational chart at depicting and clarifying the roles and responsibilities within an organization. LRC can be the key to a better future for your organization.

Notes

¹Heming, D. A. "What the Organization Chart Doesn't Show," *Supervisory Management*, Vol 18, No. 5, May 73, pp. 15-20.

²*Ibid.*, p. 18.

³LeBlanc, John. "Linear Responsibility Charting," from a videocassette, Institute of Safety and Systems Management, University of Southern California, 1974.

References

1. Murdick, R. G. and others. "Linear Organization Chart Clears Away Confusion," *Journal of Systems Management*, Vol 22, August 1971, pp. 23-25.
2. Factory, "Linear Responsibility Charting, Fast Way to Clear up Confusion," Vol 121, March 1963, pp. 88-91.
3. Manufacturing and Industrial Engineering, "Linear Responsibility Charting" (now Plant Management), February 1957.
4. Larke, Alfred G. "Linear Responsibility Chart - New Tool for Executive Control," *Dun's Review and Modern Industry*, September 1954.

AV

Item of Interest

1983 Air Power Symposium

The 1983 Air Power Symposium is to be held at the Air War College (AWC), Maxwell AFB, Alabama, from 28 Feb-2 Mar. The theme for the symposium is "Sustainability for Protracted Conflict" and various panels will discuss logistics issues. Lt Colonel Ernest Church, AWC, AUTOVON 875-2187, is the project officer.

Item of Interest

LOGCAS 83

The Third Annual Logistics Capability Assessment Symposium (LOGCAS 83) is scheduled for 14-17 March 1983 at the Air Force Academy, Colorado Springs, Colorado. Persons interested in attending or presenting a paper should contact Major Douglas D. Cochard, AFLMC/LGY, Gunter AFS, Alabama 36114. (Commercial: 205-279-4524; AUTOVON 446-4524)



CURRENT RESEARCH

AFIT School of Systems and Logistics Completed Theses and Follow-on Research Opportunities

The Air Force Institute of Technology's thesis research program is an integral part of the graduate education program within the School of Systems and Logistics. The graduate thesis research program is designed to contribute to the educational mission of AFIT's Graduate Program through attainment of the following specific objectives:

1. Give the student the opportunity to gain experience in problem analysis, independent research, and concise, comprehensible written expression.
2. Enhance the student's knowledge in a specialized area and increase the student's understanding of the general logistics environment.
3. Increase the professional capabilities and stature of faculty members in their fields of study.
4. Identify military management problems and contribute to the body of knowledge in the field of military management.

Organizations that have potential research topics in the areas of logistics management, systems management, engineering management, and contracting/manufacturing management may submit the topics direct to the School of Systems and Logistics, Air Force Institute of Technology (Captain Donald Brechtel, AUTOVON 785-3944/3809).

The graduate theses listed in this article were completed by Class 1981S and Class 1982S of the Air Force Institute of Technology's School of Systems and Logistics. AFIT Class 1981S theses are presently on file with the Defense Logistics Studies Information Exchange (DLSIE) and the Defense Technical Information Center (DTIC). AFIT Class 1982S theses will be on file with DLSIE and DTIC by January 1983.

Organizations interested in obtaining a copy of a thesis should make the request direct to either DLSIE or DTIC, not to AFIT. The "AD" number included with each graduate thesis is the control number that should be used when requesting a copy of a thesis.

The complete mailing addresses for ordering AFIT graduate theses from DLSIE and DTIC are as follows:

DLSIE
U.S. Army LMC
Ft Lee, VA 23801
(AUTOVON 687-4546/3570)

DTIC
Cameron Station
Alexandria, VA 22314
(AUTOVON 284-7633)

CLASS OF 1981S THESES

- | | |
|--|------------|
| Captain James B. Bushman
<i>Identification of an Adaptable Computer Program
Design for Analyzing a Modular Organizational
Assessment Instrument</i> | ADA 109879 |
| Captain James E. Fucillo
<i>A Review of the Air Force Bonus Pay System and
An Investigation of a Proposed Scientist/Engineer
Bonus Pay System</i> | ADA 110319 |
| Captain Frank Laras
<i>An Economic Analysis of the C-130 Wing Rotation
Concept to the "VOLANT PINE" Operation</i> | ADA 112479 |
| 1Lt Ernest E. Speck, Jr.
<i>Perceived Utility of the AFIT Graduate Systems
Management Program</i> | ADA 109878 |

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| Captain John D. Fiorini
<i>An Organizational Assessment: A Pilot Study
to Determine If A Survey Feedback Program
Produced Needed Changes In An Organization</i> | ADA 111373 |
| Captain George K. Blouin
<i>Dark Adaptation of Rated Air Force Officers
Using Electroluminescent Versus Incandescent
Light Sources</i> | ADA 110312 |
| Captain Kevin P. Hansen
<i>A Study of Time Constraints Related to Facilities
Acquisition in Support of New Weapons Systems
Initial Beddowns</i> | ADA 109777 |
| Captain James F. Karasek
<i>A Procedure for Determining the Resource
Utilization Potential of Coal Ash</i> | ADA 109877 |
| Captain Stephen W. Sickels
<i>Pre-Planned Product Improvement (P³I)</i> | ADA 110971 |
| 2Lt James W. Luginbyhl
<i>Simulation of Runoff From an Air Force Base
Using a Programmable Calculator</i> | ADA 109875 |
| 2Lt James Long
<i>Facility Maintenance Under Restricted Resources</i> | ADA 110313 |
| Major Jonathan L. Brearey
<i>An Analysis of the Impact of Multi-Year
Procurement on Weapon System Acquisition</i> | ADA 107708 |
| Captain Richard M. Taylor
<i>A Benefit/Cost Analysis Between the Blue Cross
and Blue Shield Federal Employee Health Insurance
Program and the Military Health Services System
Supplemental Campus Program</i> | ADA 110978 |
| Captain William M. McDonald and
Captain Constantinos P. Leoutseas
<i>Impact of the Shortage of Major and Captain
Civil Engineering Officers on the Base-Level
Organization</i> | ADA 110310 |
| Captain Robert J. Murawski, Jr.
<i>First to Fight: A Battle Simulation at the
Squad and Fireteam Level</i> | ADA 110320 |
| Captain Bernard J. McMullen
1Lt Nickolaos D. Papaprokopiou
<i>An Economic Analysis of Air-Conditioning Systems
With Off-Peak Chilled-Water Storage</i> | ADA 109876 |
| Major Fred H. Weck
<i>Development of a Multiple Linear Regression
Model to Forecast Facility Electrical
Consumption at An Air Force Base</i> | ADA 109880 |
| 1Lt Randie A. Strom
<i>The Prescribed Information System of Production
Control Units in Base Civil Engineering Organizations</i> | ADA 109881 |

Captain Bruce E. Simpson <i>Procuring Contracting Officers' Perceptions of the Contributions Made to Defense Cost Accounting Practices By CAS 401-416</i>	ADA 109882	Captain Michael E. Brooks <i>An Investigation of Time Series Growth Curves As A Predictor of Diminishing Manufacturing Sources of Electronic Components</i>	ADA 111375
1Lt Robert B. Barton, Jr. <i>Analysis of Company Grade Officer Positions in Air Force Base Civil Engineering and Specific Recommendations for Improvement</i>	ADA 110216	Captain Daniel Demarchi <i>A Case Study of Reliability and Maintainability of the F-16 APG-66 Fire Control Radar</i>	ADA 111387
2Lt Ricky J. McClary <i>A Review of the Usefulness of R & D Management Techniques</i>	ADA 110968	1Lt Kevin K. Rankin <i>A Predictive Validity Study of an Assessment Center For Research and Development Supervisors</i>	ADA 112121
Captain William K. Malone <i>Aeronautical Systems Division's Merit Promotion Appraisal System: An Analysis and Review</i>	ADA 111374	Captain Joe T. Horne <i>A Descriptive Analysis of Selected Affective Measures in the Maintenance Career Field</i>	ADA 111372
1Lt Gregory M. Postulka <i>Aeronautical Systems Division (AFSC) Program Management Resource Document</i>	ADA 110973	CLASS OF 1982S THESES	
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Captain Mike V. Roberts <i>Automated Drafting and Design for the Base Civil Engineer</i>	ADA 111386	1Lt Gary C. Bryson Captain David J. Husby Captain Michael E. Webb <i>A Decision Support System for Acquisition of F-16 Avionics Intermediate Shop Test Sets Using the System Science Paradigm and Q-GERT</i>	
Captain Richard S. Johnson <i>An Analysis of the Assignment of the Responsible Test Organization in Simulator Testing</i>	ADA 111022	Captain David B. Hulslander Captain Keith E. Matthews <i>A Case Study of an Aeronautical Systems Division System Program Office</i>	
Captain Dennis M. Carpenter <i>Relating Expected Inventory Backorders to Safety Stock Investment Levels</i>	ADA 110970	Captain Edward L. Whittenberg Captain Alan H. Woodruff <i>Department of Defense Weapon System Acquisition Policy: A System Dynamics Model and Analysis</i>	
Captain Steele C. Coddington, Jr. <i>Social Desirability Response Bias in the Organizational Assessment Package</i>	ADA 111196	Captain LaRita M. Decker Mr Stephen J. Guilfoos <i>Aircraft Availability: An Acquisition Decision Strategy</i>	
1Lt Ernest C. St. Gelais <i>A Simulation of the Base Civil Engineering Work Request/Work Order System</i>	ADA 110975	Wing Commander Christopher L. Mills <i>A Computer Simulation of the Structure of the Royal Australian Air Force Officer Corps: The Ros Model</i>	
Captain Max L. Proctor <i>An Analysis of Resident Satisfaction With Military Family Housing at the Proposed MX Missile System Support Bases</i>	ADA 110972	Major Bobby M. Stone 1Lt Joel D. Haniford <i>Effects of Flight Pay and Commitment on Air Force Pilot Applicants</i>	
Captain Richard G. Fedors <i>An Economic Model of Future Coal/Densified Refuse Derived Fuel Use at Wright-Patterson AFB Ohio</i>	ADA 111376		

(The conclusion of this listing will appear in the Spring issue.)



Project Warrior

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Logistics Warrior

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LOGISTICS WARRIORS: Patton and Gasoline

"To solve the gasoline shortage Patton initiated one of the most ingenious operations of the war—the Red Ball Express. This was a fleet of trucks which formed a convoy hundreds of miles long. Carrying only gasoline, they drove around the clock the 1000-mile round trip from the front lines to the gas dumps. One war correspondent who observed this operation wrote: 'I well remember passing these supply trains on the Verdun-Paris highway in September 1944, and being struck with the almost nightmarish quality of the task they were trying to perform. In the cab of each truck sat the driver, usually a negro, with a mate beside him. They drove like maniacs, hitting the bumps at full speed, rounding curves on the wrong side of the road, roaring through towns; and always the air was filled with the screeching of their brakes and gears . . . these truck drivers usually ate on the road and slept in their cabs. They were an epic fraternity. . . .' It was a typical Patton operation—fast, reckless, but efficient.

When on occasion his ingenuity failed he ordered his division commanders to fight 'until lack of supplies forces you to stop,' and when this happened he told his men to dig in. In a directive to General Eddy when he was running out of ammunition, one again sees his overwhelming desire to move forward: 'Eddy called me to state that his allowance of shells for the eighteenth was nine thousand, but I told him to go ahead and shoot twenty thousand, because I could see no reason for hoarding ammunition. You either use it or you don't. I would lose more men by shooting nine thousand rounds a day for three days than I would by shooting twenty thousand in one day—and *probably not get as far.*' Again, his usual concern for the number of casualties and his fervent desire to advance against the enemy.

The supply item which finally slowed Patton to a standstill in Europe was gasoline for his armored vehicles. For a period, it stopped entirely. He noted that 'at first I thought it was a backhanded way of slowing up the Third Army. I later found this was not the case, but the delay was due to a change of plan by the High Command, implemented, in my opinion, by General Montgomery.' Patton said of this turn of events:

It was my opinion then that this was the momentous error of the war. So far as the Third Army was concerned, we not only failed to get back gas due us, but got practically no more, because, in consonance with the decision to move north, in which two corps of the First Army also participated, all supplies—both gasoline and ammunition—had to be thrown in that direction.

Patton's drive continued, however; he told his commanders 'to continue until the tanks stopped, and then get out and walk. . . .'

Patton then called upon another aspect of American ingenuity for help. He promised three-day passes to the men who could steal the most gasoline drums—full or empty, American or enemy. The U.S. divisions of First and Ninth Armies not assigned to Third Army were on occasions stolen blind. Any shortages which existed in Patton's Army were supplemented in every possible way; and it was not unethical to get supplies from other American outfits, even though they were 'borrowed' without permission. No questions were asked by the recipients."

From: *Nineteen Stars* by Edgar F. Puryear, Jr.

LOGISTICS WARRIORS: The General Reminisces

"Every soldier of long service has his own collection of things that got snafued in the care, handling, safe-guarding and maintenance of property.

Here are three general comments:

- There is no substitute for troop duty in a company as the foundation for command and leadership at all levels—which includes a basic understanding of how to establish and maintain supply discipline.
- A periodic inventory at long intervals is not enough; continued spot checks are required. Also, when property is discovered to be lost or damaged, over and beyond 'fair wear and tear,' prompt administrative action is needed to ensure that persons responsible be made to account for it. In this way only can creeping shortages be prevented.
- The only way a commander can make certain his unit has good supply discipline is to play his part toward that end. He cannot, nor should he, try to do all the checking—he is the quarterback. His primary job is to call the signals, requiring others to carry the supply ball."

From: *Follow Me* by Maj Gen Aubrey "Red" Newman, USA (Ret).

LOGISTICS WARRIORS: Soviet View of War

"War is a country-wide preoccupation in the Soviet Union. Historical experience, a domestic political system heavily dependent upon the perception of external threat, and nuclear age geopolitics combine to make the threat of war and the need for massive military forces persistent realities for the ordinary Soviet citizen. World war, even in the nuclear age, *is* thinkable. It is contemplated often.

They intend to be prepared in every possible way to place the brunt of battle, with or without weapons of mass destruction, on the adversary. But Russians have lived on past battlefields and, though they will do their best to avoid it, they probably live on one of the main battlefields of the next major war. For them it is the battlefield on which the victor, if there is to be a victor, will be determined. War will probably be a global affair, but victory and survival have a distinct continental focus in the Russian mind.

The political implications of Soviet military power are understood and appreciated. New license for the projection of Soviet power and influence exists under the growing Soviet nuclear umbrella. This license is being carefully explored by a leadership mindful that security of the homeland must always enjoy top priority. There is also increasing latitude for productive political and economic accommodations with potential adversaries. This, in the Soviet view, is mostly because of Soviet military achievements.

But the *politics* of military power must never be allowed to interfere with the *requirements* for potential conflicts. Forces must be built for fighting and winning. Political influence can only, in the Soviet view, flow from forces designed to carry the day in combat.

The Soviets' perception of war in the nuclear age by no means concentrates on nuclear weaponry to the detriment of conventional forces. Nuclear weapons may be decisive but *all* types of forces, and a

militarized populace, will be required for any hope of survival and victory. A vast panoply of military power, constantly modernized and disposed to secure Soviet territory from 'outside' threats, enjoys broad support in the Soviet Union.

The Soviets do not want war. They cannot, however, fail to note that expansion of military power has been their primary claim to superpower status. No observer of Soviet domestic and foreign politics should expect Soviet military power to diminish, but neither should he expect the USSR to deliberately initiate a major war. The security of the USSR far outweighs the goals that any nuclear-age Marxist-Leninist is likely to pursue.

Still, Soviet attitudes toward the conduct of war are unsettling. There is a clear preference for the initiative and the establishment and maintenance of a crushing offensive that, even divorced from Soviet intent to use war for political ends, is frightening in the nuclear age. In the face of massive and growing Soviet military power at all levels of conflict, and the probability that Soviet decisionmakers would have little appreciation of restraint once the conflict has begun, these preferences for the initiative and offensive are more salient than the judgment that the Soviets do not want war."

From: *Soviet Perceptions of War and Peace* by Steve F. Kime, edited by Graham D. Vernon.

LOGISTICS WARRIORS: Doctrine and Its Utility

"It is hazardous to give too much credit to any tactical doctrine; the conduct of battle is often very decentralized. Yet, doctrine exists to give order to these efforts. Despite the German defeat in the First World War, the German efforts in tactical doctrine deserve close attention. In the development and application of new tactics for their army, the Germans generally displayed superior ability. The German doctrine achieved the balance between the demands of precision for unity of effort and the demands of flexibility for decentralized application. With clearly stated principles, the doctrine provided thorough, consistent guidance for the training, equipping, and organizing of the army. However, this consistency was not rigid, for in its battlefield application, the doctrine provided sufficient flexibility to accommodate the demands of local conditions and the judgment of several commanders. In examining this accomplishment some tentative generalizations are apparent.

Methodology was a factor in German success. No tactical concept remained in the isolation of pure theory. The better German tacticians judged ideas according to the actual environment in which they would be applied. Their evaluation considered all influential factors: the condition of German forces, the enemy situation, weapons, terrain, space, and time. No tactical concept was a thing-in-itself with inherent strength: concepts crossed the gap from theory to reality. For example, the counterattack was not valuable simply because it was a 'counterattack'; a counterattack *would* be valuable if it were delivered at the proper time by well-trained units on known terrain against a confused enemy. The Germans did not neglect the cause and effect relationships. They did not lull themselves into a sense of satisfaction by simply coining a catchword or catchphrase. Their tactics were viable principles to adapt to the battlefield, not impressive labels to hide ignorance. It is perhaps instructive to note that the German offensive tactics of 1918 did not receive a catchy name until the Allies tried to give them one (which was inaccurate, anyway)."

From: *Leavenworth Papers* (No. 4) by Timothy T. Lupfer.

LOGISTICS WARRIORS: Early Simulations

"Rand's work in the application of man-machine MSGs [models, simulations, and games] to problems of both operational and

experimental interest was carried out by the Logistics Systems Laboratory (LSL), primarily in the late 1950s. Various groups within the Department of Defense had already sponsored considerable research on problems of logistics and inventory management. There was, however, a large gap between the results of this research and their practical implementation. LSL was a man-machine approach to help bridge this gap. Basically LSL was intended to provide a sufficiently reliable representation of the real-world environment of Air Force logistics systems to permit testing and comparison of policies and procedures. It would also attempt to assist in transferring the results of research, modified by experience gained in the laboratory setting, to operations in the real world.

Laboratory Problem I (LP-I) was LSL's first major task. It was designed to test logistical policies and procedures for the Air Force and to indicate ways of implementing them. The potential policies were incorporated into a system (Logistics System 2) and compared with the actual configuration (Logistics System 1). The two models were evaluated under identical circumstances described in terms of numbers of aircraft to be maintained, flight programs, and other conditions; the comparative effectiveness of their policies and costs was also calculated. Next, a rapidly changing aircraft program was simulated. The experiment provided for phasing aircraft in and out of inventory over a five-year period, during which use factors—frequency, duration and type of missions flown—for each aircraft were varied in ways assumed to be realistic. The properties of the simulated aircraft were derived from a study that selected 800 out of a possible 15,000 parts to reflect differences in price, demand, reparability, importance, and so forth. A special malfunction model was designed and used to give identical malfunction patterns for similar flights using either logistics system.

Each simulated day took about an hour of running time in the laboratory. The experiment ran for fourteen simulated quarters, during which two wars were simulated; it took four months to conduct. The staff of LSL included about thirty professionals, twenty clerks, and various supporting personnel to program and operate the computer. Fifteen players operated each of the two systems. Work began on LP-I in early 1957 and continued until the end of the year. In the fall of that same year, work commenced on Laboratory Problem II (LP-II) and continued until late 1958. Unlike its predecessor, LP-II stressed the development of systems; specifically, it was an attempt at a study of the Ballistic Missile System, which had not yet been fully developed. The basic aim of LP-II was to help develop a set of operating and support policies for the evolving system. In 1960, the Air Force created a team to evaluate LP-II and the techniques it had used, with the following major conclusions being reached:

1. Laboratory simulations can be valuable tools for use in evaluating the design and application of military systems.
2. Benefits accrue from a reduction in the time and cost of system-development processes.
3. Combat effectiveness can be improved through better design of systems.
4. Laboratory simulation can be useful in generating and comparing certain classes of operational and logistical systems and policies.
5. Laboratory simulation does not eliminate the need for operational tests.
6. To be effective, facilities for laboratory simulation should be in close proximity to Air Force system-project offices. Constructing a single laboratory-simulation facility for the entire Air Force appears to be unsatisfactory, but there appear to be practical advantages to concentrating work in a few major installations.
7. Simulations of systems for Air Force decision-making purposes should be performed in house rather than by contractors."

From: *The War Game* by Garry D. Brewer and Martin Shubik.

AF

"When a crisis hits, the forces must go to war as they are, not as they'd like to be."

F. Clifton Berry, Jr.
Air Force Magazine

“Since the character of contemporary weapons is such that their production as well as their use can dislocate whole economies, it is probably not too much to suggest that the survival of entire cultures may hinge upon an ability to perfect superior weapons and exploit them fully. Survival itself, then, appears to depend on speed in both the development and the utilization of weapons.”

Ideas and Weapons by
I.B. Holley, Jr.

Air Force Journal of Logistics
Air Force Logistics Management Center
Gunter AFS, Alabama 36114